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The Convergence Of Urban Plan Features: A Comparative Examination Of Trends In Canada And England

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THE CONVERGENCE OF URBAN PLAN FEATURES: A COMPARATIVE EXAMINATION OF TRENDS IN CANADA AND ENGLAND

by

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ABSTRACT

The broad context of this work is the problem of environmental diversity, and the specific approach taken is the evaluation of changing levels of diversity with regard to the particular cultural indicator of urban morphology. The author explores the extent of morphological similarity between national sets of cities, and provides a conceptual framework for the explanation of increasing similarities in form through time. Empirical work is limited to the physical structure of cities, and particularly to their ground-plan features, by reason of their permanence and amenability to study through large-scale plans.

The analysis is undertaken using comparative data for ten Canadian and ten English cities, collected at two levels. Firstly, for all twenty built-up areas, a one in four sample of $(500m)^2$ quadrats is characterized with respect to six variables of street layout, in order to determine intra- and inter-national differences, and to assess spatio-temporal trends in design and density. Secondly, taking one representative city in each country, temporal trends in residential layout design, housing densities, and coverage ratios are assessed for five time periods using archival plans.

Both levels of analysis focus on the identification and measurement of morphological convergences (increasing form similarity through time) and divergences (increasing disparity). Trends are identified both with respect to layouts developed in successive

periods, and to the evolving urban plan-composites. From 1880 to the present, extensive between-nation convergence is evident for all plan features studied. But, in all cases, the rate of convergence through time has slackened markedly during this century, and currently may be characterized as relative rather than absolute convergence. Thus, for example, absolute differences in net dwelling densities per hectare were smallest in inter-war developments, but in current developments the larger disparity is smaller relative to increased median densities in both countries.

The identified trends of convergence are discussed with reference to the concept of homogenization, defined as increasing similarity due to the adoption of shared innovations. Thus, shared transport improvements decreased densities in both countries, shared design criteria produced convergence in street layout design and plot coverage ratios, and shared planning concepts were largely responsible for recent increases in density. Temporary divergences occur due to lags in adoption. It is concluded that complete homogenization has not come about due to intrinsic constraints on the development markets, such as levels of prosperity and pressures on land-supply, which are not affected in the short-run by the cross-diffusion of innovations.

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CHAPTER I

A CONCEPTUAL FRAMEWORK--THE CONVERGENCE OF URBAN PLAN FEATURES

1. Problem Definition

> The clear trend is that those who live in a large city or its suburbs anywhere, whether Cadiz, Cairo, Calcutta, Canton, Caracas, Chicago, or Christchurch, despite certain functional and social differences, are coming to have more in common in their ways of life than they have in difference.
> (Spencer and Thomas, 1969, 278)

Whether an overstatement or not, this quotation is expressive of numerous observations concerning the process of "cultural convergence" as it applies to city life. Cultures express themselves in the form of their physical environments, but the reverse is also true. To paraphrase Winston Churchill, we shape our cities and afterwards our cities shape us.[1] Many of those who design portions of the urban fabric, and those who study the effects of these designs on human life-styles, agree. They explicitly suggest that physical environments determine the likely range of spatial perceptions and spatial behaviours available to their inhabitants.[2] If urban areas are increasingly

[1]Churchill's actual comment, "We shape our buildings, and afterwards our buildings shape us," referred to the relationship between the interior design of the House of Commons and the parliamentary system. It is often quoted in relation to urban design (e.g., Gutheim, 1963, 113, and Michelson, 1970, 168).

[2]For examples of research embodying this assumption, see particularly the important integrative work by Michelson (1970),

similar in physical form, it is probable that aggregate patterns of human activity may also take on greater uniformity from place to place. In this sense, a lack of diversity in urban environments may be accompanied by a lack of diversity in human perceptions and behaviours. The reverse may also be true; that an increasing homogeneity between human modes of life might be expected to produce increasingly similar built environments.

Whether or at what scales of environment and behaviour diversity is desirable is a broad question on which speculation and debate continues.[3] But, as a basis for working towards a consensus on such questions, it might surely be useful to know the existing degrees of diversity in the patterning of human environments at different scales, and the rates at which differences from place to place are increasing or decreasing. We also require a framework for the explanation of such degrees and rates, allowing an understanding of the process by which separate urban entities come to display similar characteristics.

These broad requirements set the context for the narrower and more specific aims of the present research effort; namely, for certain

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notably Chapter Eight. Also, see the volume on behaviour and environmental design by the Research and Design Institute (1969), and the annotated bibliography on the subject by Bell, Randall and Roeder (1973).

[3]Rene Dubos (1968) has argued for diversity in surroundings, and sees dangers in cultural homogenization. A common theme in architecture and civic design is the need for variety. Stephen Kaplan (1973, 279) makes the point that variety from place to place, providing it is patterned rather than random, defines regions and therefore provides legibility. In the same vein, Gutheim (1963, 110) notes that order (meaning a constant framework) "leads but to monotony and deadness," and Rapoport and Kantor (1967) call for complexity in environmental design.

plan features in two sets of cities, to explore the extent of current form dissimilarities, to assay whether there has been a trend towards greater or less similarity, and to offer a framework for understanding these matters in terms of the market systems which determine characteristics of plan increments.

In terms of overall organization, the sequence of this report is as follows. First, reasons for limiting the research to the physical structure of urban environments, and particularly to aspects of their ground-plan, are put forward. Following a discussion of the mechanisms by which form convergence or divergence between sets of cities might be produced, a market model is presented to suggest the specific mechanisms applicable to convergence/divergence in the design and density characteristics of site-level developments. This model particularly stresses innovation and diffusion processes, and is intended to serve as a framework for the later interpretation of empirical data. Comparable data on plan features are then collected at two levels; firstly, at a rather small geographical scale for a number of cities in two national areas, in order to determine current intra- and inter-national differences with particular reference to the street-plan; and secondly, in greater detail for a representative city in each national area, with emphasis on the recent historical trends in residential layout design and housing densities. Through reference to currently planned residential developments in these cities, short-term future trends of similarity and diversity are suggested. Finally, conclusions on the research findings are made with respect to the original model and in light of other studies.

2. Convergence and Divergence of Urban Plan Forms

The urban physical form may be divided into three fundamental categories: (1) the town-plan; (2) the building fabric; and (3) the pattern of land and building utilization (Conzen, 1968, 116). Of these, the first two are less open to change than land-use and therefore represent, in any one city, a more complete historical record of influences on urban structural organization.[4] They are thus more suitable for a study of historical trends. But the study of trends in the design and scale of individual buildings is better dealt with by an architectural rather than a geographical approach,[5] since it involves specialized appraisal at a very detailed scale. This leaves the town-plan as the most suitable category for the geographic investigation of form similarities. The writer follows Conzen (1960, 4) in defining the town-plan as the two-dimensional arrangement of an urban built-up area in all its man-made features. It includes the three distinct plan elements of streets, plots, and the plan arrangement of buildings.

An increasing similarity in the plan characteristics of different urban areas may be thought of as a convergence of the areas, represented as the approach of points in variable-space. By extension, if the plan characteristics of the two urban areas become

[4] For example, data presented by Clawson (1971, 175) suggest a "half-life" of about 80 years for residential structures. That for road layouts is considerably longer.

[5] There is, however, some geographic work on patterns of house types. And Johnston's (1969) study of the spatio-temporal diffusion of such types within Melbourne has some relevance to the notion of intra-city homogenization.

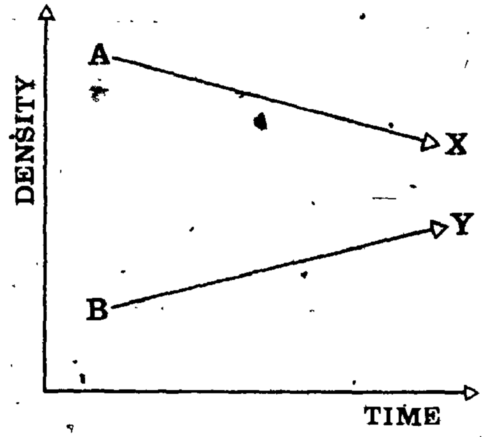
increasingly dissimilar (represented by points moving apart in variable-space), we may use the term divergence. The notion of convergence within non-physical space is by no means new; for example, it has been used with respect to time-space (Janelle, 1968), with reference to cultural differences by Spencer and Thomas (1969), and in relation to levels of technology by Horvath (1974a). Both Janelle and Horvath have attempted the measurement of rates of convergence, and for their problems convergence is identified simply as an absolute decrease in distances separating points along one dimension. Here, however, the concept will be applied to a variable-space of several dimensions, rather than one, each dimension being related to a particular characteristic of plan-design or density.

This introduces several problems with respect to the definition of convergence. For instance, on one variable, two cities may become increasingly similar through time, but they may diverge in some other respect. In such a case, should one attempt to construct a weighted average movement to determine whether there is overall convergence or divergence? Also, given the nature of the variables to be employed, convergence of two cities on any one variable may be absolute or relative. To illustrate, the sketches below portray, for a measure of density,

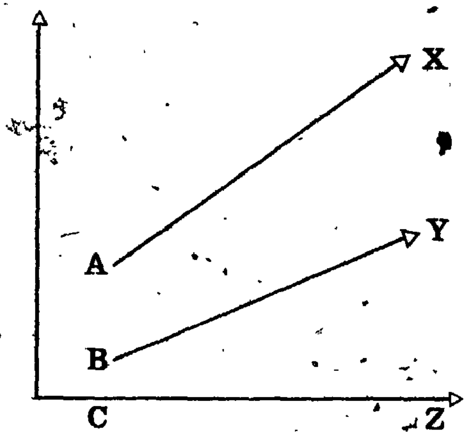
(1) a situation of absolute convergence, in which distance AB > XY,

(2) a situation of relative convergence, in which AB < XY, but AB/AC > XY/XZ:

(1)



(2)



It should be apparent that absolute and relative convergence may occur simultaneously, and also that there may be absolute convergence occurring with relative divergence.

However convergence is defined, by what types of process is it likely to come about? It is the author's contention that to hypothesize rapid convergence in variable-space, one must assume that some type of homogenization process is operative. The term homogenization is used here somewhat analogously to its meaning in biological taxonomy, in which homogeny between two taxonomic units refers to similarity of form due to common ancestry (see Sneath and Sokal, 1973, 77). With respect to two urban areas, it is defined as similarity of spatial patterning owing to the operation of a shared influence which has been adopted in both areas but which has a common point of origin. Thus, urban homogenization may be thought of as the result of diffusion processes.[6] That is, some force or influence on morphology, whether a

[6]Innovation diffusion has been defined as "acceptance over time of some specific item, idea or practise by individuals, groups, or other adopting units" (Katz, Levin and Hamilton, 1963). Geographers

technology, a philosophy, a value system, or an institutional mechanism, is invented or originated at some point of inception, and is then taken up elsewhere. It produces similar effects on form wherever it is adopted (i.e., similar effects of the same cause). Homogeny may be distinguished from a situation of homology, in which structural correspondence or similarity of form is evident, but is due either to (a) "independent invention" (similar effects of similar causes, or (b) similar effects of dissimilar structuring forces.

Why would one expect increasing homogenization of urban forms through time and between regions? In his study of diffusion processes between national urban systems, Pederson (1970, 203) notes general agreement on the fact that the speed of diffusion between places increases as their volume of interaction grows. Since interaction within and between groups of cities has been increasing at a seemingly geometric rate, it might be reasonable to suggest that the rate of homogenization has also been geometric.

The adoption of an innovation may be viewed in two lights, as a qualitative phase during which there either is or is not adoption at each of a set of places, and a quantitative phase during which the extent of adoption at various places may be compared by means of some ratio (Horvath, 1974a, 4). For example, the spread of television was characterized first by a qualitative phase of transmitter construction, then by a quantitative phase in which the ratio of receivers per 1,000

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have paid particular attention to the nature of this diffusion as a spatial process. For an excellent bibliography of their research in this area, see Brown (1968). Brian Robson (1973) devotes an entire book to the effects of innovation diffusion on differential growth rates within a system of cities.

population was the critical adoption criterion. Horvath gives an illuminating argument on the effects of an innovation on a set of regional units characterized initially by complete similarity. Here, any innovation will at first produce both qualitative and quantitative divergence (increasing dissimilarity), since only certain units will adopt, and the adoption ratios throughout the set will be markedly different. Once the rate of adoption for the whole set begins to decline, however (that is, at the inflexion point), there will be an increasing convergence of individual adoption ratios, until there is again complete similarity when all units have reached some intrinsic adoption limit (Horvath, 1974a, 14).

This argument has a bearing on the problem of urban form. Suppose a set of non-interacting cities in a region, each growing through time. They are likely to show some dissimilarities in form due to disparate forces operating to mould the development process. If these cities then institute communications and begin to interact fully, thereafter any relevant innovation in the system will influence the form of incremental development such that, towards complete adoption, new development in all cities is affected in the same way. Given a continuing series of such innovations and rapid diffusion, extensions to the urban area during any period of time will be essentially similar in all cities. The dissimilar core areas will remain for some time, but will become an increasingly smaller proportion of each city. Therefore, through time, the composite form of each city will become more similar to the forms of its neighbours within the region. This inference may be stated a little more formally:

> Given a set of growing urban units (either individual cities or regional sets of cities), any increase in interaction between the units will lead to increasingly greater similarity in the composite forms of the units.

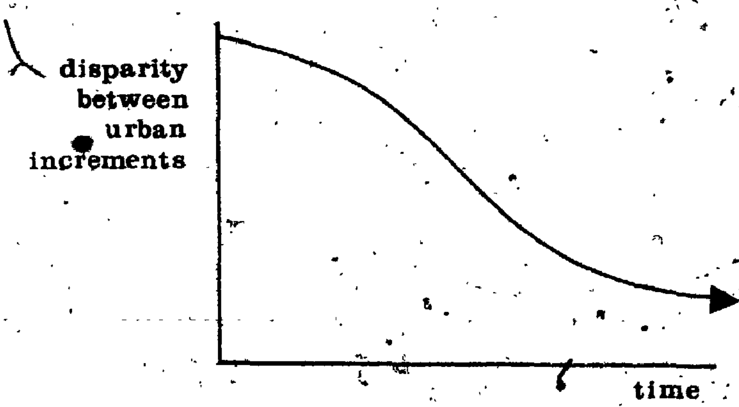
The argument just made supposes a rather abrupt increase in interaction from a zero level to some higher constant level. It is more realistic to assume a gradual process of easier communications and more rapid diffusion of relevant innovations. Thus, new extensions to urban areas at time t will exhibit less similarity within the set than those at t + 1, since interaction and therefore speed of adoption are greater in the later period. Not only will the composite or aggregate forms be more similar through time, but new developments occurring in successive time periods will be progressively more similar. That is:

> Given steadily increasing interaction between a set of growing urban units (either individual cities or regional groups of cities), the form of incremental development in the units will be increasingly similar in successive time periods.

These inferences are simplistic in that they suggest that differences from place to place will decrease at an increasing rate through time, through a progressively greater similarity in factors operating on the development process. But this disregards the possibility that particular cities or groups of cities may operate under intrinsic constraints which are not, in the short run, capable of being displaced or greatly modified by outside influences. Examples would be, for a single city, particularly marked and inhibiting topographic controls, or for a national group of cities, levels of prosperity or pressures on land supply. Homogenization is most likely to occur via diffusions altering the nature of extrinsic (easily modifiable) factors such as transportation technology, legislative framework, and favoured design solutions. Broader processes of diffusion, for example of the urban/industrial mode of economic organization, may indeed affect intrinsic factors such as the level of prosperity, but the time-spans involved are considerably greater. Logically, one would therefore expect that two groups of cities would display rapid form-convergence only to the point where all extrinsic factors are similar, but that thereafter convergence would continue more slowly if at all, in response to increasing similarities in broad intrinsic constraints. This may be stated as a third inference:

> Given that there are certain intrinsic constraints which alter only slowly through time, convergence of urban units may be conceptualized as a logistic curve of disparity against time, such that disparity decreases at an increasing and then decreasing rate.

Diagramatically:



Obviously, the greater the initial differences between cities or groups of cities, the greater the potential for absolute form-convergence.

This third inference will be treated as a working hypothesis in this research. To foreshadow later results, the rationale leading to its statement will prove particularly useful in the explanation of empirical morphological convergence trends.

There are at least three scales at which, as a geographer, one may attempt to discern homogenization of the urban physical form. One may study variations within particular cities, within systems of cities, or between systems of cities. At the risk of infringing on the architect's scale of concern, one might also examine whether there is increasing homogeny within sections of the city, for example at the residential neighbourhood level. If the values, standards and technology influencing structural development are increasingly adopted uniformly both within and between cultures, then on the basis of the inferences made so far we should expect to detect convergence at all four scales.

The basic purpose of the research outlined in this dissertation is to explore the validity of this expectation. This will involve examination of two national sets of cities for which there is evidence of increasing international diffusion of ideas and technologies bearing on urban development.

What types of innovations are likely to affect urban form? Basically, structural patterns may be characterized with respect to their design features, expressed as aspects of spatial patterning, and with respect to the density or scale of pattern. A framework for viewing major innovation effects in terms of both design and density will now be presented.

3. The Density and Design of Urban Layouts: Innovation Effects

The structural landscapes of cities "reflect countless decisions and actions from the time of settlement to the present"

(Borchert, 1967, 301). And the decisions affecting the layout of any particular development are themselves taken by numerous actors working with different goals within the framework of a market mechanism.

Most structural development is in the form of housing. Land use studies of North American cities show residential uses ranging around 32 percent of developed property area, the largest single land use.[7] With associated streets and ancillary land uses (e.g., schools and developed open space), upwards of 60 percent of developed area is residential, and the figure is even greater when considering only new urban development. In outlining the decision-making system, therefore, reference will be made largely to the new housing market, particularly as this type of development has considerably more impact on perceptions and modes of living than industrial, commercial, or institutional developments.

Residential developments may differ with respect to population and area sizes, street and plot layout design, density, type of unit, and dwelling-group design. These characteristics are arrived at largely by the decisions of the producers rather than the consumers.[8] The production side itself may be divided into the actual producers

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[7]Two comparative studies are by Harland Bartholomew (1955) and the RAND corporation (Niedercorn and Hearle, 1964). Their figures on the proportion of developed land in residential uses diverge considerably (28 and 39 percent respectively) and the findings of the Chicago Area Transportation Study (given in Berry and Horton, 1970, 445) seem to provide a reasonable intermediate figure (32 percent). Lithwick (1970, 102) quotes figures for Ontario cities giving approximately 56 percent of developed areas in gross residential uses.

[8]We are talking here of the mass functionalist housing markets developed in western nations over the last hundred and fifty years.

(developers, builders, and builder-developers), and what may simply be called site planners. Lynch (1971, 3) defines site planning as "the art of arranging the external physical environment to support human behaviour," and notes that it lies along the boundaries of architecture, engineering, landscape architecture and city planning. While it is practised by members of all these professions, Whyte (1970, 242) laments that "one of the most difficult things to find out in studying . . . developments is who, if anybody, was responsible for the final site plan." In smaller developments, the developer and planner will often be the same man, and only the larger and more successful developers use trained land planners.[9]

Closed Free Market Situation

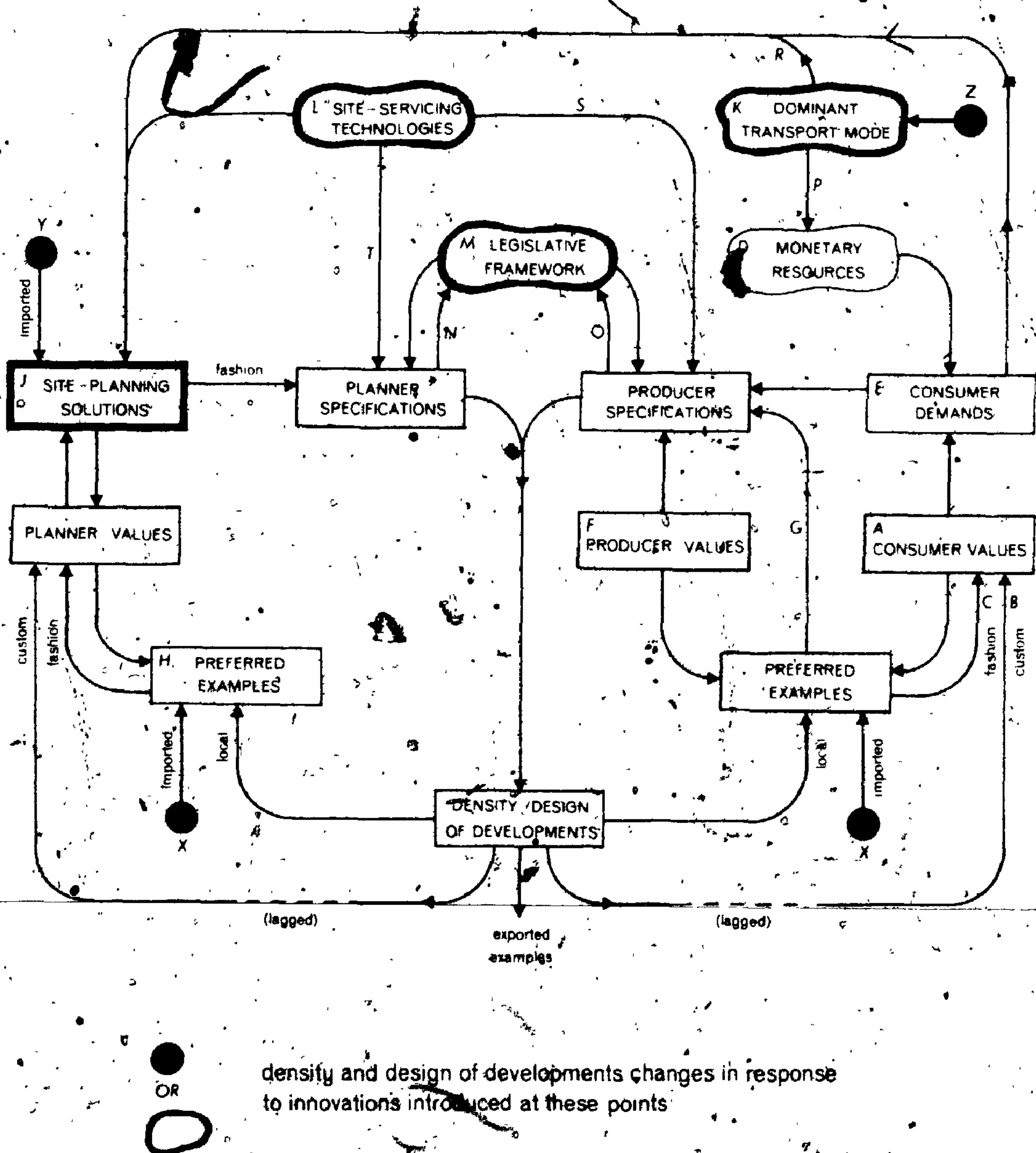
Turning to a model of site planning decisions, consider first a simple free market system (either a single city or a system of cities), which is closed to outside influences. Here, there are no regulative mechanisms provided by legislation to control or influence design characteristics, and no innovation effects from outside. (This is represented by Figure 1, minus the legislative framework box and importation arrows.) Within this system producers, planners, and consumers all possess certain values with regard to residential development.

[9] In the U.S. context, smaller developers usually do the basic planning themselves, and "for professional assistance they tend to favour ex-surveyors or engineers whose principal expertise is an ability to squeeze in the maximum number of lots the rules will allow" (Whyte, 1970, 242). Thus, in such cases, the planner's values can be assumed to mirror almost exactly those of the developer.

FIG 1

INNOVATION EFFECTS WITH RESPECT TO THE DESIGN AND DENSITY OF URBAN DEVELOPMENTS

see text for descriptive explanation of the lettered items



The consumer's design values (labelled A in Figure 1) are largely concerned with the quality and appearance of the individual dwelling unit, but it has been demonstrated that aspects of physical layout at the neighbourhood scale are also important (Michelson, 1966). Certainly, the consumer has preferences with regard to density since other things being equal a large lot is generally seen as desirable. Figure 1 portrays the fact that the consumer's values are largely learned in the context of a given physical and cultural environment (B). This mitigates against rapid change in consumer tastes, since what is preferred in new developments (C) will not differ greatly from the familiar and known (i.e., customary). Michelson goes so far as to state that "what is known and experienced is rated highly no matter how unfavourable it may be to an outsider" (1970, 165). The consumer, of course, works under the constriction of monetary resources (D), which translate his values into an effective demand (E).[10]

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[10]A note on the effectiveness of the producer in meeting consumer demands. It should be pointed out that the decision process outlined in the model does not operate as an ideal market due to the nature and structural life of the product. The product examined here is the residential development as a whole rather than the individual dwelling unit. The density and design of the site layout has positive or negative utility to the dwelling-unit purchaser in terms of externality effects . . . the visual quality of the surroundings, the amount of privacy, adequacy and safety of vehicular and pedestrian access, and so on. The cost of site planning and servicing is included by the developer in the dwelling-unit price rather than as a separate item.

Repeat business is unlikely, but the developer is presumably concerned to build up a general reputation for supplying demanded environments at fair prices. His only real guide to the nature of these demands is his experience of the marketability of previous developments (both his own and those of his competitors). The site planning of a new development cannot possibly be influenced by potential buyers, since these are at the time unknown to the developer. To quote Kevin Lynch (1971, 258): "The ultimate user plays no active part in site design. His needs are represented by vague intentions, by general restraining

The developer's values in this system (F) are largely concerned with profit-maximization, and these values are assumed to remain constant. Profit-maximization determines which examples of current development are preferred as models for, or inputs to, the design of, future developments (G). That is, once a successful formula has been found, it will be retained until there is definite evidence of other formulae being even more popular with the consumer. Thus, like the consumer, the producer is unlikely to experiment with new design innovations; he is basically conservative.

Given that the developer has hired a professional site planner, however, there will be a certain degree of conflict between planner and producer values. The planner, particularly if trained architecturally, is imbued with a certain philosophy and exposed to numerous contemporary, historical and theoretical examples of planning solutions (H). He aims to provide environments which satisfy certain aesthetic criteria and encourage certain desired human behaviours.[11]

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rules and standards, or by the indirect signals of a market oriented to effective economic demand. . . . Site plans serve the interests of developers first--and the interests of those able to pay for their use second."

[11]A note on the effectiveness of professional designers in meeting consumer demands. Michelson (1970, 133) asks, "By what non-user values are planners, architects . . . and other creators guided? To what extent are they guided by the values and other characteristics of users? . . . . Do they learn professional ideologies which guide their work?" It may be that the very fact of self-selection for design careers suggests different sets of values from those of the average consumer, but training is also important, and one would expect value-differences between designers trained at different schools (R. Kaplan, 1973, 272). Studies by Leff and Deutsch (1973) and R. Kaplan (1973), admittedly using small samples, suggest definite differences between designers and clients both in the description of environment and in environmental preferences. Although designers generally express

These aims are not always even indirectly compatible with the producer's profit motive. Influential designers, for instance at architectural schools, may be partially divorced from the constraints of the market and able to afford the luxury of innovative design (J). As consultants, other designers are the agents for the diffusion of innovative designs within the system. Given that transportation (K), and site-servicing (L) technologies remain constant, site planning solutions developed by designers are the only major source of innovation in this closed housing market (see Figure 1).

Closed Regulated Market Situation

Ideally, a free market is an efficient mechanism for catering to the needs of individual consumers. However, certain negative externality effects (for example, leap-frogging sprawl[12]) may bring about the legislation of a regulatory system to ensure that the community as a whole is not penalized by private profit. Often, the legislation itself only sets up a machinery by which certain codes and standards may be adopted and policed.

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interest in satisfying human needs, they have a tendency to anticipate these needs without consulting the consumer, and an even greater tendency not to solicit the views of residents in existing projects. In the words of an influential site-planner, "designers often assume their own values and disregard those of the future inhabitants" (Lynch, 1971, 5).

[12]For a discussion of the nature and economics of urban sprawl, see Harvey and Clark (1965). William Whyte (1970) has much to say on the costs of sprawl and the positive aggravation of sprawl caused by exclusionary zoning (see particularly his Chapters 2 and 3). Essays on particular aspects of the problem are included in Gottmann and Harper (1967). Despite the negative views of sprawl engendered by the planning ethic, there remains the countervailing view that the advantages of the free market situation far outweigh its disadvantages.

Although types of legislative machinery (M in Figure 1) are themselves subject to innovation and diffusion effects--for instance, the spread of comprehensive zoning ordinances in North America after 1916--the form of the machinery has little direct effect on the design of site plans. For the standards of "good practice" explicit in such procedures as subdivision control and site plan control originally emanate largely from the design professionals (N) and producers (O) themselves (see Lynch, 1971, 241, and Ontario Economic Council, 1974, 36). Indeed, a regulated market may be less open to design innovations simply because the codified standards almost automatically disallow departures from existing site planning solutions.[13]

It is suggested that planning legislation has most effect on site plans in terms of densities. This may occur either as a direct or as an indirect effect. Indirectly, restrictions on the supply of developable land, and delays for approval, force the developer to lower lot size and increase densities to maintain profit levels. In particular, site costs are likely to rise relative to the income levels of marginal buyers, which levels determine the selling price the builder can fix for his completed house--"The most obvious way he can avoid the dilemma is to economize on land by raising the densities of his housing" (Clawson and Hall, 1973, 54).

Directly, planning policy may, given the twin goals of efficient urban services and land conservation, be aimed specifically at raising

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[13]See Whyte (1970, Chapter 12) for some problems encountered in introducing cluster-planning to U.S. subdivision design.

the densities of housing developments. This has been the situation in the United Kingdom since 1947.[14]

Open Regulated Market Situation

In discussing the model in Figure 1, it has so far been suggested that modifications to contemporary site design and density are to be expected only from the diffusion of novel planning solutions originated by local design professionals (whether engineers, architects, or land-use planners). If, however, exogenous factors affecting the decision-making system--notably the dominant transport mode and available site-servicing technologies--are allowed to vary, other innovation effects come into play.

In terms of the transport mode (K), Borchert (1967) distinguishes four major epochs in American history characterized by a dominant technology "crucial" to the form of cities and city systems. Transport modes in these epochs, most recently the "auto-air-amenity" era, "brought major changes in land-use patterns, densities, lot sizes, nodality of the central business district, and other intraurban variables" (307). It is a common theme that, ceteris paribus, mass automobile ownership effectively decreases the relative cost of suburban living (arrow P) and therefore allows the gratification of consumer space demands through low density residential development.[15]

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[14] Some discussion of direct and indirect effects of planning with specific reference to Canada and the U.K. is given in Chapter VI, Section 2.

[15] For example, see Fleisher (1961), Boal (1970), Sargent (1972), and Lansing and Hendricks (1967).

Besides density effects, street-plan designs must be accommodated to such a transport innovation. Thus, in the case of automobile travel and access, engineers in particular have been called on to suggest innovative solutions to maximize safety and minimize access costs. New transport technologies in a sense act to force changes in site planning criteria (note arrow R) and are therefore suggested as a major innovation source in Figure 1.

Site-servicing technologies assume considerable importance for the developer. Servicing includes the provision of plot-access and utilities such as water and power, plus the necessary sewerage- and runoff-disposal facilities. Particularly in supply and disposal technologies using utility line systems, per capita costs of installation and maintenance are related negatively (although not necessarily linearly) to density, and reinforce the producer's desire to build at high density.[16] Thus, currently-favoured technologies, and innovations with respect to site-servicing, strongly affect producer density specifications (arrow S), and also are of concern to municipal planners in terms of regulatory action (arrow T).

One further exogenous factor affecting site densities in particular is effective consumer demand for space. This will increase if relative purchasing power (D) increases. Crompton (1961, 202)

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[16] Figures provided by Downing (1969, pages 35 and 53) suggest that the marginal cost of septic tank systems per capita per year is higher than for sewer lines at net densities over about 25 persons per hectare (depending upon community size and distance to treatment plant). If the only servicing possibilities for a site are driven wells and septic tank sewerage, the Community Builders' Council (1960, 111) recommends a minimum lot size of 20,000 square feet to avoid contamination, giving a maximum net density of only about 20 persons per hectare.

mentions an increase in general prosperity as influencing standards and demands regarding residential layout.

Diffusion between Market Systems

Aside from innovations occurring within the local market system, there may be linkages with surrounding systems and therefore a constant import and export of values, ideas and examples regarding urban design. If the local system we are considering is a single city, one would expect increasing interaction with the rest of the national area to produce forms of development which are increasingly similar to all others in the nation. This occurs through the importation of preferred examples affecting the values and criteria of planners, producers and consumers (arrows labelled X), by the adoption of externally-originated site planning solutions (arrow Y), and by sharing of transport technologies (arrow Z). Similar diffusions will occur between integrated national systems once interaction is established between them.

Regarding the international diffusion of a planning solution, this is best exemplified by the history of the Radburn principle. The basic cluster or superblock design utilized ancient ideas evident in, for example, the English and New England village green. Clarence Stein and Henry Wright studied features in Britain in designing their plan for Radburn, New Jersey, built in the late 1920's (Stein, 1957, 41-48). Thus, there was an importation of preferred examples which, through the filter of the designers' values and objectives, led to the innovation of a formal planning solution. Although some examples of the design were developed in the U.S., adoption was stalled by: (a) the conservatism of consumers and producers; and (b) regulative criteria not designed to handle the new plan form. The principle was exported back to Europe, where it thrived, and has recently been re-imported into North America with reference to preferred examples of European practice.

A more ubiquitous example of international diffusion effects is the gridiron street plan, a rational plan solution ideally suited to real estate marketing purposes. Diffusion also occurs in the dissemination of research results comparing cost-efficiency and consumer satisfaction in various planning approaches.

Aside from formal design solutions in the professional literature, certain developments tend to be adopted internationally as exemplars of excellence, and reviewed repetitively. Favourable descriptions of design features in Radburn, Reston, Stevenage, or Vallingby are predictable contents in standard design texts. Although the consumer is less exposed to such exotic examples, for all decision-making groups there is a certain "fashion" effect with respect to design preferences (denoted as such in Figure 1).

One further factor which is subject to within-nation and between-nation diffusion effects is the dominant transport technology to which site-planning solutions are adapted. Although improvements in transport may occur locally, they may also be imported, so that the factor may be viewed as extrinsic in terms of our earlier discussion.

4. Summary

In this introductory chapter, some specific research requirements relating to the broad problem of urban environmental diversity have been identified. These relate to the identification of degrees of difference from place to place, and of rates of form convergence and divergence between places, and to the provision of a suitable framework for the explanation of such degrees and rates. A general discussion of mechanisms by which form-convergence may occur has been presented, but the present research will concentrate on the particular case of residential site planning. The notion of homogenization via innovation and diffusion effects was illustrated for this case by a decision-making model, which identifies specific sources of innovations affecting the design and density of developments.

The following chapters outline empirical research designed to investigate the effects of an homogenization process as they are evident in refractory plan features. No attempt will be made to substantiate suggested causal links in the market model itself, or to trace the history of specific site planning innovations as they diffuse through a system of cities. Rather, the purposes are both more basic and more general; selecting two national areas which, with the rest of the western world, have increasingly shared more similar economic, technological and social conditions, they are:

(a) to describe the current degree of similarity in the design and scale of plan features;

(b) to determine whether plan forms have become increasingly similar through time, and assess the rate of this convergence effect internationally (between national sets of cities), intranationally (within national sets), and at the intra-urban scale (within particular cities;

(c) to suggest explanations for these degrees and rates couched particularly in terms of the homogenization concept introduced in this chapter.

CHAPTER II

RESEARCH DESIGN AND METHOD

1. Organization of the Study

To determine the nature of form-convergence, one needs to compare the present and past morphologies of cities in at least two countries. These countries should display increasingly similar technological and economic bases, and be characterized by increasing interaction in the urban planning and development fields. This study will in fact be limited to only a pair of such countries. More would be preferable, but this would involve data collection tasks beyond the capabilities of a single researcher.

To provide both breadth and depth, the study is organized in two major parts: macro-scale work giving a generalized picture of a single plan element in a number of cities, and micro-scale work for two cities which examines all three major plan elements.

The initial analysis takes a selected set of medium-sized cities in each country, and examines their present urban forms to determine the extent of within-nation and between-nation variation. Owing to the very detailed scale of analysis necessary for study of other plan elements, the macro-scale comparison is confined almost exclusively to the street plan. Several descriptions of street plan design and density are collected for a number of sampling areas within each city, on a strictly comparable basis. Summary measures relating to each city are then graphed and subjected to a component analysis to discern covariation of variables and the extent of overall difference between the national sets.

Utilizing the same data on street plans, an assumption concerning the concentric growth of urban areas through time will be utilized to gain a graphic estimation of temporal trends. This should allow identification of any convergence process operative, and give an indication of which plan aspects are most subject to such a process.

The second part of the analysis is aimed at providing more concrete evidence on convergence and divergence. For this, one representative city in each national area is selected, and archival materials are used to assemble detailed information on developments occurring in several time periods. In terms of the street plan, some verification of the macro-analysis is possible here, both in substantiation of the concentric growth assumption, and in a comparison of actual and assumed trends. For buildings and plots, attention is focussed primarily on net dwelling-unit densities through time, and their relationship with street layout designs and overall site planning. This approach is intended to provide information on trends in within-city diversity, both as it applies to each development increment through time, and to the evolving urban composite.

Major trends identified will be discussed in terms of the innovation-diffusion concept outlined in the preceding chapter.

2. Sampling Procedure

Choice of Countries

Cities in Canada and England[1] will be compared in this study. Major reasons for selecting these countries are the author's relative familiarity with them, and the ready availability of source materials. But, also, plan forms in the two countries are not so dissimilar as to present difficulties of comparison, and they are reasonably representative of two major types of urban history in the western world.[2] In accord with the fact of an increasingly global information net and urban/technological base, they share a large body of common technological, cultural, and institutional factors operative on the development process.

One could argue that in cultural matters generally the two countries, although sharing increasing interaction, have gradually become less influential on each other, since their interactions with other nations have grown even more rapidly. But this is not necessarily true regarding matters of urban plan development, and further, the

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[1] I specify England rather than Great Britain since the Scottish urban tradition has developed somewhat differently from that in England and Wales. Scotland's inclusion would, in fact, necessitate the comparison of three rather than two national sets, increasing the study's generality at the expense of its depth. It might be argued that the Québec cities are similarly different from those in anglophone Canada, but in terms of street-plan characteristics, this may only be true for Québec City.

[2] English plan forms are generally representative of the European urban tradition, characterized by accretionary growth affected by ancient cadastral patterns. They contrast markedly with the regular cadastral basis of cities in Canada and other areas of European settlement such as the U.S., Australia, and parts of South America and Africa.

homogenization concept is not predicated so much on relative ties as on absolute levels of interaction and exchange. Starting from relatively dissimilar conditions of urban plan development prior to the urban/industrial revolution, the two countries have increasingly been subject to similar overall bases of transport technology and market organization. Intrinsic constraints such as pressure on land supply and levels of consumer prosperity have not necessarily become monotonically more similar through time, but there appear to have been diffusion effects in terms of extrinsic factors. For example, relatively large numbers of architecturally-trained British planners were imported into Canada by the Central Mortgage and Housing Corporation during the 1950's (Ontario Economic Council, 1973, 39), and were influential in shaping an emerging planning idiom. Prior to this, English planning concepts and examples were familiar to Canadian townsite planners, but in neither country were such design notions capable of wholesale implementation. Although developers are not themselves a major source of site planning innovations, a further pointer to diffusion effects is the increasing presence in Canada of British developers such as Wimpey, Costain and Bevis.

It should be evident to the reader that urban development processes in Canada and England interact largely through world-wide "pools" of professional information, shared values, common technologies, and similar market conditions. Thus, increasing similarity between their plan forms would not necessarily imply a direct diffusion of innovations affecting these forms from the one country to the other; many such innovations may diffuse to each via a third country. Canada and England are therefore treated here not as an isolated two-nation system, but simply as examples of a larger international process.

Relative to all world cultures, Canada and England have historically been very similar in terms of culture and technology, and should therefore provide a good test of the working hypothesis (namely, that convergence describes a logistic curve through time). For recall that the potential for form-convergence is positively related to the extent of initial form-disparities; if cities in Canada and England have been convergent during any period, one might well assume that absolute convergence has occurred much more rapidly between national groups which were initially more dissimilar.

Sampling Within Cities

The procedure for sampling the street plan within chosen cities will determine the number and size of cities which it is possible to study. And the sampling design at this level must reflect the most suitable scale for the identification and measurement of the street plan indicators under analysis. Plots and building outlines are best studied at large scales of at least 1:5,000, but the street layout is readily identifiable in plan form on topographic maps at scales of 1:25,000 and 1:10,000. For measurement of the street plan indicators outlined below, therefore, 1:25,000 topographic maps will be used, partly because more recent and complete coverage is available at this scale.

Pilot work suggests that meaningful statistical description of a road layout requires examination of a reasonably extensive area of development, around 500 metres square, so that unusual or insignificant features do not bias characterization of the layout. However, using sampling units as large as a square kilometre would produce loss of information, since particularly in older sections several site layouts, perhaps of greatly different character, might be developed within such an area. Cities will therefore be divided into $(500m)^2$ sampling units for the purpose of the macro-scale analysis.

This still poses problems, since only a few medium-sized cities (of approximately 100,000 to 300,000 population) could be exhaustively surveyed using such units. And reasonably large urban areas are preferable since they are subject to a multiplicity of decision-making forces and are more likely to reflect steady growth over time. Rather arbitrarily, therefore, a one in four sample of $(500m)^2$ cells will be selected for ten such cities in each country (this turns out to provide sample sizes of from 21 to 107 cells per city).

Urban Area Delimitation

For each city it is necessary to delimit the urban area throughout which the one in four sample is to be taken. To base this delimitation simply on the political boundaries of the central city would exclude areas of recent development in the case of underbounded cities, and therefore distort the interpretation of summary statistics of the street plan in such cities. It is, therefore, desirable to delimit the extent of the actual built-up area. This may be done in a fairly subjective manner, as with the Canadian census definition of metropolitan urbanized cores,[3] or by the detailed examination of building patterns.[4]

Since there are no comparable surveys of built-up areas in Canada and England, it was necessary to devise for this study a simple method for delimitation based on the evidence of 1:25,000 topographic maps. Using a grid of km.² quadrats centered on the city centre, the built-up area is defined as all contiguous quadrats containing at least thirty[5] hectare parcels in which there is a building.[6] Contiguity is defined as adjacency of quadrats along at least one side (rook's case). The only exception is to disallow lengthy attenuations or ribbons extending from the main urban body; along a ribbon, not more than two quadrats connected on less than three sides to other built-up quadrats are included.

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[3]Defined as the "continuous built-up area covered by street pattern design and meeting a density of 1,000 persons per square mile." No criteria are given as to what in any particular case constitutes "continuous" or "street pattern design".

[4]Stig Nordbeck (1971) describes the Swedish census definition of built-up area--each included house must lie within 200m of an already included house. In his twin cities study, Borchert (1961, 50) defined square mile units with over 80 intersections as urban.

[5]This appeared to be the most suitable arbitrary limit in pilot studies. Owing to differences in the scale and spatial extent of Canadian and English urban areas, however, this limit may exclude functionally dependent suburban areas (in the English case). Quadrats containing water bodies were included if 30 percent of the land area hectares contained a building.

[6]On O.S. English 1:25,000 maps, approximate building outlines are shown throughout the urban area. But on N.T.S. Canadian sheets at the same scale areas of small buildings (generally dwellings) are mostly shown by red tint outlining the areas of both buildings and their plots. Only in low-density peripheral areas are buildings individually marked. A certain degree of judgement is required when using the N.T.S. sheets in order to gauge the presence or absence of a building within a hectare quadrat, but the degree of subjectivity introduced is minimal.

In selecting one of the four $(500m)^2$ quadrats within each $km.^2$, that quadrat with the largest number of "built" hectares is taken, and in the event of a tie preference is given in turn from the northeast corner clockwise. This introduces a systematic bias which ensures that selected quadrats display a fairly developed street pattern, suitable for descriptive measurement. The advantage of strict comparability is retained.

Choice of Cities

A further problem is posed in the selection of ten representative medium-sized cities in each country. Rather than do this in a completely subjective manner, the only available comparative urban populations,[7] compiled by Kingsley Davis (1969) and the International Urban Research group, are used. Their method of delimiting urban areas is based on the functional-area criteria used in U.S. Census Metropolitan Area definitions.[8]

[7] Various methods for urban area delimitation have been suggested (see, for example, Grytzell, 1963, Borchert, 1961 and Philbrick, 1961). However, comparable delimitation and population estimation for all world cities (defined as towns over 100,000) is restricted to the work by International Urban Research (1959) and Davis (1969).

[8] Davis's delimitation procedure is given in World Urbanization 1950-1970, Vol. 1 (1969), pp. 25-33. Basically, an urban area is defined by a central city of at least 50,000 population, plus all contiguous local government areas where non-agricultural workers are at least 65 percent of the labour force. For the U.S. and U.K., place of work and telephone call data were also used. Cut-off limits for the contiguous areas were established by a density rule based on the assumption of a continuous decline in density from the city centre.

Using 1971 census figures for Davis's metropolitan areas,[9] there are just ten Canadian cities in the range 100,000 to 300,000 population. These figures (given in Table 1) are generally somewhat lower than those for the 1971 Canadian Census Metropolitan Areas, but greater than for Census Urbanized Cores. The survey date of latest available 1:25,000 maps[10] is noted, along with the approximate population of the delimited data area for that year. Since it happens that no Quebec cities are included using the Davis figure as a criterion, Trois Rivieres-Cap de la Madelaine is also subjected to analysis, as a comparative guide. It had an estimated population of 80,000 in the 1963 data area. Otherwise, the ten selected cities represent practically the full set of medium-sized cities in Canada, drawn from all regions (four in Ontario, three in the Atlantic provinces, two in the prairies, and one in British Columbia). Appendix E gives their location and suggests that their residential environments are representative of those within Canada and Canadian urban areas generally. One major study examining variations in Canadian urban structures is by King (1966), but almost all variables included in his factor analysis refer to economic, social and demographic aspects

[9] For the Canadian cities, Davis's 1970 estimates were checked against 1971 census populations of his delimited areas (basically the 1961 Census Metropolitan areas). The maximum difference was 15,000 for Sudbury and Kitchener-Waterloo.

[10] Map materials used for built-up area delimitation and for the macro-analysis of street plans were as follows: St. John--21G/8a (1960, 1h (1960), 8b (1961), 1g (1961); St. John's--1N/10b-a (1961), 10c (1961); Saskatoon--72B/2a, 2b, 2g, 2h (all 1963); Sudbury--41I/10d, 11a, 6h, 7e (all 1963); Regina--72I/7g (1962), 7h (1962); Victoria--92B/6f-g (1959), 6e (1959); Halifax--11D/12h, 12g, 12a (all 1969); Kitchener-Waterloo--40P/7h (1965), 8e (1964); Windsor--40J/3h, 6a, 7d, 2e (all 1960); London--40I/14f, 14g, 40P/3c, 3b (all 1961); Trois Rivieres--31I/7a (1963), 1:50,000 31I/7 (1970).

TABLE 1

CITIES SELECTED FOR MACRO-SCALE ANALYSIS--POPULATION ESTIMATES AND SURVEY DATES

City	Populations for Areas Delimited by Davis* (000's)	Survey Date of 1:25,000 Maps Used	Estimated Population of Delimited Data Area** (000's)
CANADA:			
St. John	106	1960/61	70
St. John's	120	1961	70
Saskatoon	126	1963	100
Sudbury	140	1963	80
Regina	140	1962	110
Victoria	193	1959	140
Halifax	213	1969	170
Kitchener-Waterloo	227	1964/65	110
Windsor	235	1960	160
London	236	1961	160
ENGLAND:			
Lancaster-Morecambe	106	1964/66	90
St. Helens	126	1964	110
Cambridge	138	1965	100
Northampton	150	1950	100
Burnley-Nelson	173	1958	130
Oxford	195	1963/65	120
Chesterfield	225	1958/60	70
Mansfield-Ashfield	236	1958/70	140
Blackpool	251	1958	170
Preston	282	1958	150

*1971 Census of Canada, 1961 in England.

**To nearest 10,000, estimated for survey dates.

rather than characteristics of the physical plant. It is even difficult to judge from King's study whether the cities are representative in these aspects, since factor scores are not given. They do, however, distribute themselves among the major groupings given by King.

For both 1960 and 1970, Davis lists thirty English cities with functional area populations between 100,000 and 300,000. Since 1971 census figures were not available during the formulation of this study (and since the populations did not change greatly during the decade anyway), 1961 populations for Davis's delimited areas were used to list these cities in order of size. Ten cities were selected by the arbitrary device of starting with the smallest city and taking every third one in turn. They are listed with the survey dates[11] and estimated populations of the data areas in Table 1. A location map and data on physical form are given in Appendix E.

These cities were examined with respect to the mapping of all British towns over 50,000 by Moser and Scott (1961), in which each town is located in component space according to its scores on two major components--social class and stage of development. They mirror

[11]As for the Canadian cities, the latest available editions of 1:25,000 topographic maps were used. In several cases, the last major revision was in the late 1940's or early 1950's, and for these cities supplementary information from enlarged 1:63,360 maps was used to maintain reasonable comparability with the Canadian data (which are all post-1959). Maps used were: Lancaster-Morecambe--SD46 (1950), 45 (1966), 1-inch 89 (1964), 94 (1958); St. Helens--SJ49 (1952), 59 (1949), 1-inch 100 (1964); Cambridge--TL45 (1951), 46 (1952), 1-inch 135 (1965); Northampton--SP75 (1950), 76 (1950), 1-inch 133 (1950); Burnley-Nelson--SD83 (1950), 1-inch 95 (1958); Oxford--SP50 (1965), 40 (1957), 1-inch 165 (1963), 158 (1956); Chesterfield--SK37 (1949), 36 (1949), 47 (1951), 1-inch 111 (1960), 112 (1958); Mansfield-Ashfield-SK56 (1950), 46 (1950), 45/55 (1970), 1-inch 112 (1958); Blackpool--SD33 (1951), 34 (1951), 1-inch 94 (1958); Preston--SD52 (1951), 53 (1951), 43 (1951), 1-inch 94 (1958).

the national distributions on these components very closely, and appear to form a representative sample.

One assumption regarding the choice of sample cities should be made explicit. Arbitrary population limits of 100,000 and 300,000 have been used in making this selection, since they bracket cities with sufficient historical and structural variety of plan development for analysis, but which are not of unmanageable size. It is assumed, however, that cities of both larger and smaller size are subject to very similar processes of plan development and would in fact be described by similar scores in the following analysis. During any period of development, large cities will tend to exhibit a greater range of new plan forms, layout arrangements, and building densities than will small cities. But the most typical (modal) developments occurring within built-up areas will be similar regardless of city size (with perhaps just a slight lag in innovation adoption as one moves down the size continuum).

3. Street-Plan Indicators

For reasons already outlined, the macro-analysis will concentrate on the street pattern as an expression of overall morphology. Aside from the sheer space taken up by urban streets,[12] they are the most important plan feature in a number of ways. Both Conzen (1960, 7) and Watson (1959, 127) note the relict nature of street layouts, their

[12] See Bartholomew (1955) and Owens (1968) for estimates of proportions of urban land in streets. As Bartholomew notes (112), "streets, by occupying 27.6 percent of the total developed area, absorb the largest amount of land of any single use in urban areas."

longevity and resistance to change. They represent a very heavy capital investment which determines the form of adjacent interstices, the "holes in the net" (Lynch, 1971, 129-130). Martin (1972, 10) argues that "the pattern of the grid of roads in a town or region is a kind of playboard that sets out the rules of the game," and suggests that "the maximum efficiency of [site] planning is measured by the relationship of circulation to gross area" (Martin and March, 1972, 31).

What are the relevant descriptive variables denoting the design type and scale of street layouts? What aspects of street patterns are most significant in terms of costs, safety, and aesthetic appeal? As Lynch and Rodwin (1958, 202) note, descriptive possibilities are endless, but "description works best when there is enough familiarity with significance to permit vividness and terse accuracy." It is felt that the following indicators not only accord with designer evaluations of significance, but permit terse description of what is admittedly a very complex problem. They are applicable to the evaluation of street layouts at the scale of $(500m)^2$ quadrats.

Road Density

In their proposals for the analysis of urban form, Lynch and Rodwin suggest the possibility of measuring road density as the intensity with which channels are packed into a given unit area (1958, 205). Carter (1972, 142) proposes a similar density measure, and it has actually been employed in studies by Borchert (1961) and Caminos, Turner and Steffian (1969). Borchert's measure was in miles of street per square mile, while Caminos et al., working with $(400m)^2$ layout sections, used m/ha.

Density measures may be given in either gross or net terms, and there is much confusion as to the use of these terms in urban studies, particularly between disciplines. Here, gross road densities will be computed as the road length in relation to total unit area, net densities in relation to the amount of the unit actually built-up (taken as the hectare parcels containing buildings). The net density measure is obviously the more useful, since it represents a virtually completed stage with little possibility of change due to further development or infilling. It indicates road density within developed sites, albeit rather approximately at this scale of analysis.

Definition: Gross Road Density = Total road length in each $(500m)^2$ quadrat, expressed in kms per km^2

Definition: Net Road Density = Road length in developed areas of each quadrat, expressed in kms per km^2 of such areas.

Both gross and net road density are measured using an opisometer run along the middle of route symbols.

Road Junction Frequency

The frequency with which road junctions are encountered along a unit stretch of road is of consequence to the vehicular traveller in terms of safety considerations, and this is taken into account by road engineers (Leibrand, 1970, 242). Lynch points out that intersections entail special costs not only directly but also since they require road length that otherwise would be developed as frontage (1971, 129). Thus, a measure of junction frequency not only supplies further evidence of layout density, but also some information regarding cost efficiency and safety.

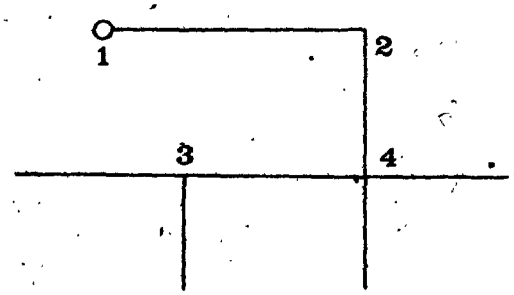
Road junctions will be defined analogously to vertices in graph theory, being any convergence or crossing of routes, dead-ends on culs-de-sac, and abrupt changes of direction along road sections.

Definition: <u>Road-Junction Frequency = Total number of junctions divided by total road length, expressed in junctions per km of road.</u>[13]

Kansky (1963, 24) gives an inverse measure to the one proposed here, namely the average length of sections within a network, and terms it the theta index.

Road Connectivity

The average number of road sections meeting at intersections and junctions indicates the degree of connectivity in the road net. As shown, at a four-way intersection, the number is obviously four, at a three-way three, and at the termination of a cul-de-sac one. Where two straight road sections meet to produce a sharp change in direction, the junction connectivity is two. Thus, a mean connectivity measure of four suggests a grid pattern, whilst a low figure around two suggests a great number of culs-de-sac. Detection of such culs-de-sac is very



[13]As far as the writer is aware, no author has used a similar measure, although Borchert (1961) combines junction frequency and road density in one measure--intersections per square mile. This correlates very highly with gross road density.

useful since they have important engineering and behavioural implications.[14] For traffic flow and safety, the fewer sections at a junction the better.[15]

Definition: Road-Connectivity = Average number of road sections meeting at junctions.

In terms of network analysis, this measure corresponds to the average valency of nodes within the network, and is therefore twice the β index of the network (see Kansky, 1963, 16).

Angular Deviation at Junctions

It is generally accepted that for safety reasons, junctions should be approximately at right angles (for examples, see Lynch, 1971, 142). Also, 90° intersections cut down on distorted lot shapes and therefore improve cost effectiveness. Road patterns which have grown organically, however, tend naturally to follow desire-lines and therefore display few such right-angled junctions. I will term a junction angle within 10° from a planning norm of 90° regular, and more

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[14] Cul-de-sac and loop layout designs are compared favourably with grid layouts by nearly all writers. In terms of cost, they greatly reduce the amount of road per unit area for equal dwelling densities and lot sizes, and also allow lightly-built minor streets at lower cost (see comparative plan analyses by Kostka, 1957, 67-80, and Ontario Community Planning Branch, 1958). For the consumer, they discourage through traffic and thus provide privacy and pedestrian safety.

[15] For example, T-intersections have only three theoretical traffic conflict points as compared with 16 in a four-way intersection (Tunnard and Pushkarev, 1963, 90).

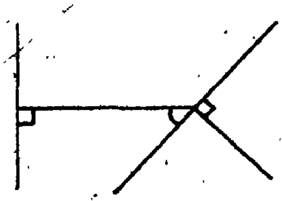
acute[16] junction angles irregular.

Definition: Angular Deviation at Junctions = Proportion of all intersection angles[16] which deviate by more than 10° from a norm of 90°, expressed as a percent.[17]

Road Curvature

A further important feature of site layouts is the extent to which the roads form a rectilinear or curvilinear pattern. For the engineer or site designer, curvilinear layouts are preferred for reasons of safety and speed reduction (Community Builders' Council, 1960, 140), and for visual interest and closure. Tunnard and Pushkarev (1963, 104) note that in engineering terms, curvature is measured by the angle enclosed by a 100-foot arc--that is, a one degree curve is one whose length is 100 feet for each one degree of internal angle that it moves through. Alternatively, curvature may be measured by length of radius (Lynch, 1971, 142). Such measures are not possible at the scale of

[16] Only the more acute angle is measured at each junction. Thus, one angle is measured at a T-junction, two angles at a four-way intersection. By way of examples, the layout shown here contains two right-angled junctions and one "deviant" junction.

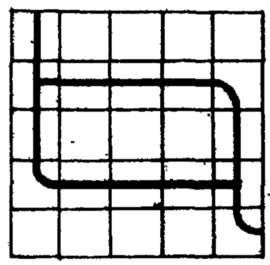


[17] Carter proposes a different measure, namely "the mean angle at which streets intersect in each small unit" (1972, 147). However, if all angles are included for this measure, the mean would almost certainly by 90°, and computation only for the more acute angles is extremely time-consuming and prone to error at the 1:25,000 scale. Johnston (1968) used a binary classification, with the cut-off criterion being whether a census district had two or more intersections not at 90°.

1:25,000. Johnston (1968) uses as an indicator the number of individual street sections which contain a curve or inflexion, and the method of measurement used here is very similar.

Definition: Road Curvature = For those hectare parcels containing a section of road, the proportion in which a curve or inflexion is present.

For example, in the layout diagrammed here, out of 25 cells, only 14 contain a section of road, and of these 14, three contain curved sections. Curvature is therefore 3/14, or 21 percent.



All six of these indicators have been tested for measurement error by repeated measurement of a sample street layout at the 1:25,000 scale. On this basis, they are deemed appropriate both in terms of efficiency and accuracy.[18]

4. A Street-Plan Typology

How do the plan indicators outlined above aid the identification and labelling of particular types of street layout? There have been numerous rather subjective typologies or classifications of such

[18] For four sample quadrats, error was expressed as the average range of values around the mean measurement, as a percentage of the mean. The angular deviation measure showed greatest variation, but this was only seven percent. Thus, none of the measures for $(500m)^2$ quadrats is likely to be greater or less than seven percent of the assumed true value.

layouts, by both geographers and site planners. Generally, geographic typologies are descriptive only of the pattern itself, and tend to be value-free. Also, they often refer to the total pattern design of streets within towns and cities, rather than to particular areas of development. Thus, Dickenson (1945) and Tricart (1954) use three basic classes of ground plan--irregular, spider-web, and rectangular. The rectangular forms are further divided into rib, parallel-street, and grid plans. Pillsbury (1970) uses a similar scheme for characterizing the layouts of Pennsylvania villages, and Whitehead and Alauddin (1969) employ it in categorizing Scottish towns.

Site planners generally agree on nomenclature, and label plans by the more significant features within them--e.g., gridiron, long block, internally-developed block (superblock), cul-de-sac, and loop systems (Kostka, 1957). And planner descriptions often also include an assessment on density, generally in terms of dwelling units rather than street length.

The six street-plan indicators above each refer to a particular aspect of plan, and in fact there is no a priori reason why any of them should be correlated or associated with any other. A cul-de-sac system, for instance, could display regular or irregular junctions, high or low density, and be rectilinear or curvilinear (in practice certain combinations are more likely than others). Layouts should therefore be characterized for each major aspect separately. And one should allow for the fact that many plans are of mixed or intermediate design, and cannot necessarily be described as one thing or the other.

Based on judgements concerning the full range of plan measures collected in the twenty sample cities, the following distinctions are made as an aid to the objective description of layout types.

Net Road Density:	Over 17.0 kms per km^2 = high density Under 11.0 kms per km^2 = low density
Angular Deviation:	Over 30 percent = irregular Under 15 percent = regular
Connectivity:	Over 3.3 = grid Under 2.6 = cul-de-sac
Curvature:	Over 30 percent = curvilinear Under 15 percent = rectilinear

Thus, a particular plan segment will be classified only with respect to its most distinctive features, in the order given here--for instance, a regular grid rectilinear plan. Also, it is quite possible that some segments might remain unnamed, if their scores for each street-plan indicator lie in the mid-range. This is considered a merit of the typology rather than a difficulty, since it is unwise to attach any label other than "intermediate" to such cases.

5. Summary

To summarize the research procedure outlined in this chapter, the study is basically arranged into two parts:

(a) a macro-scale analysis of ten Canadian and ten English cities, examining the current similarity of street-plan and their possible homogenization.

(b) a more detailed analysis of all three plan elements in two cities representative of the national sets.

Reasons for the choice of countries and cities have been outlined, as have the methods for urban area delimitation and for sampling within each built-up area. For the macro-analysis, six indicators of street-plan design and scale have been defined, and some justifications for their use given. A typology of street layout types may be constructed from these indicators. The following two chapters are devoted to an interpretation of data on these indicators for the twenty sample cities.

CHAPTER III

MEASURES OF THE COMPOSITE STREET-PLAN--TWENTY CITIES

Having followed the sampling procedure outlined in the previous chapter, summary measures for each city were obtained. In each city, and for each street-plan indicator, the mean and coefficient of variation of the values for the $(500m)^2$ quadrats were computed; this gives twelve measures to describe the composite of street-plan layouts in each city. (See Appendix B for sample sizes in each city.)

The composite measures, therefore, summarize the patterns of layout for each city as a whole entity. However, they say nothing with regard to the temporal trends in scale or design within that city. Coefficients of variation are used to suggest the degree of internal spatial variation within each city, and the degree of homogeneity or heterogeneity of the total existing street-plan.

The following is an examination of these composite measures both graphically and through statistical description. An attempt will be made to note the nature and extent of differences between the Canadian and English groups, and also any sub-group within these. Since this chapter will deal with each city in total, it bears on the notion of morphological homogenization only in the sense that it sets out the current degree of international and intra-national similarity.[1]

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[1]Or rather, the extent of similarity at the sampling dates, which range from 1958 to 1970 and which are here assumed to be roughly equivalent.

1. Description of Composite Street-Plan Measures

Here, the mean for each descriptor is graphed against the coefficient of variation (C.V.). No attempt is made to weight any of the descriptors as being more important in terms of its significance in the perception of urban physical structure. Each city has been located in the two-variable spaces to give an indication of its position relative to that of others. Canadian cities are denoted by circles, and English cities by square symbols.[2] The reader should bear in mind that the mean and C.V. of a descriptor for a particular city are calculated from the distribution of scores pertaining to the sample of $(500m)^2$ quadrats in that city.

Ellipses of density, or standard ellipses, are used to illustrate graphically the centre of each national distribution, its amount of dispersion, and the shape and direction of the dispersion. That is, they are centered on the centre of gravity, rotated to minimize variation on one axis, and encompass one standard deviation either side of the centre of gravity on each axis.[3] Obviously, this centrographic approach is not always very meaningful, since on some measures the sample cities tend to form sub-groups rather than national clusters;

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[2]Since Trois Rivières has been included in the graphs for reference only, it is denoted by an open circle. The values for this city were not used in constructing the Canadian density ellipses.

[3]The Standard Ellipse was proposed by Lefever (1926) as a description of the shape and spread of a distribution. A good summary of its construction and properties is given in Lee (1966). The centres of gravity, angles of rotation, and rotated variances required to construct the ellipses in Figures 2 to 7 were derived using programme SPACE, written by M. Goodchild, Department of Geography, University of Western Ontario.

nevertheless, the density ellipses suggest pairs of variables on which there is some overlap between national groups.

Gross Road Density

On this descriptor, the English cities generally exhibit a higher mean, as one would expect owing to the greater amount of older stock, the lag in automobile adoption, and the pressures on land consumption (see Figure 2). As a group, they do not cluster around an average value to the same extent as the Canadian cities--the Lancashire towns in particular are above the average English mean of 13.7 kms. per sq. km. Burnley-Nelson has a strikingly high mean density of 18.9 kms. per sq. km. Two southern towns with much modern development--Oxford and Cambridge--seem indistinguishable from the Canadian cities in terms of both mean and C.V., and lie within the Canadian standard ellipse.

The average mean for Canadian cities is 11.2 km. per sq. km. Only Saskatoon and Regina differ greatly from this (with 14.0 and 13.8) and this is partly owing to their compact nature which sets gross density almost equal to net density. Conversely, the lowest Canadian densities (particularly Sudbury) may be ascribed to the influence of rough and difficult terrain, which forces low gross densities.

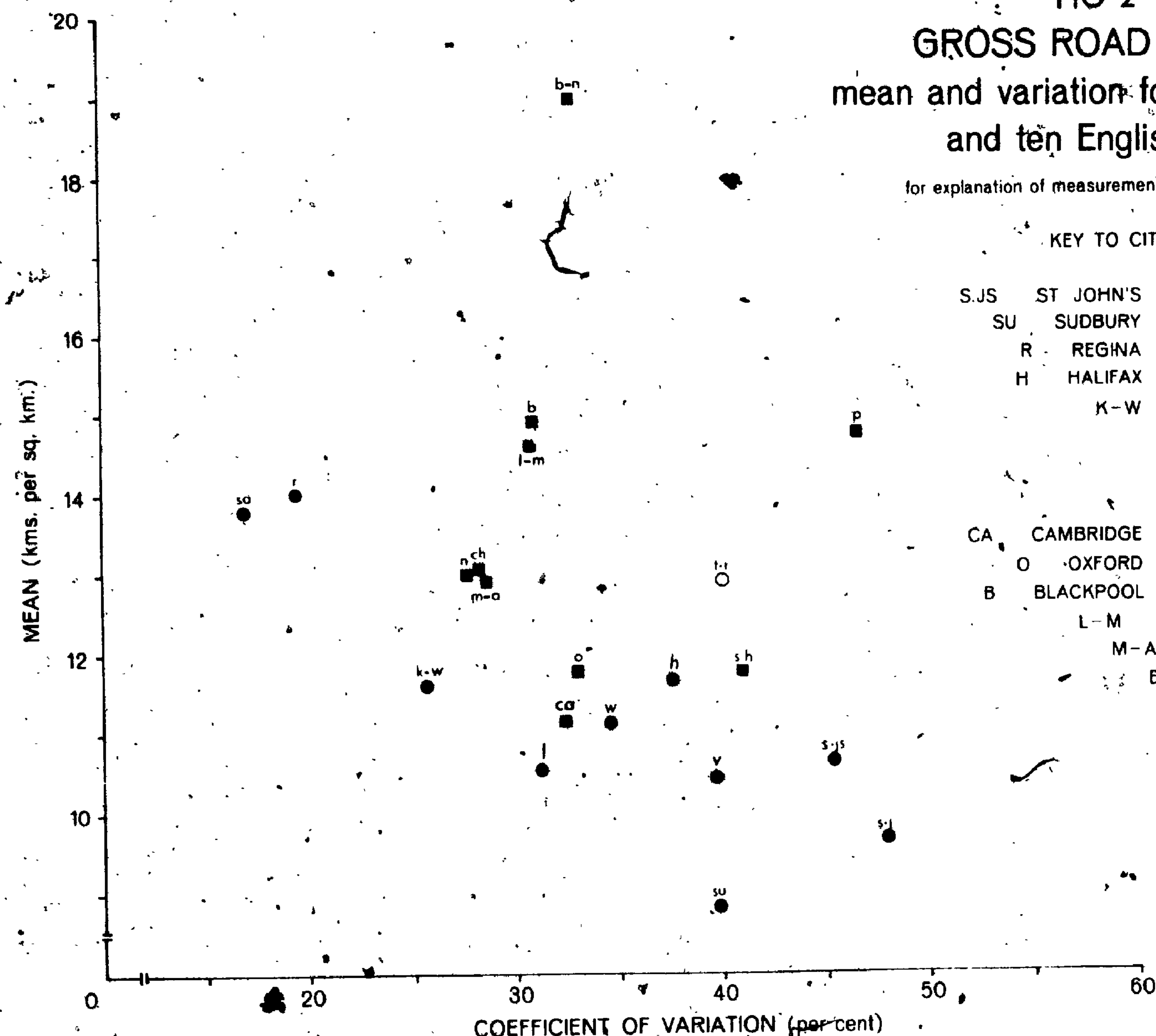
The Canadian cities are distributed in a linear fashion, with the mean inversely related to the coefficient of variation. This is reasonable, since their central densities do not vary greatly, and a low mean therefore implies particularly low gross densities at the periphery--hence, high variation over the city as a whole. It is worth noting that Preston, which has a fairly high mean and great

FIG 2
GROSS ROAD DENSITY
mean and variation for ten Canadian and ten English cities

for explanation of measurement procedure see text

KEY TO CITY ABBREVIATIONS

S.JS	ST JOHN'S	S.J	ST JOHN
SU	SUDBURY	SA	SASKATOON
R	REGINA	V	VICTORIA
H	HALIFAX	W	WINDSOR
		K-W	KITCHENER-WATERLOO
		TR	TROIS RIVIERES
		L	LONDON
CA	CAMBRIDGE	S.H	ST HELENS
O	OXFORD	N	NORTHAMPTON
B	BLACKPOOL	CH	CHESTERFIELD
		L-M	LANCASTER-MORECAMBE
		M-A	MANSFIELD-ASHFIELD
		B-N	BURNLEY-NELSON
		P	PRESTON



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variation, must therefore include very high gross densities in its central area, which is the case.

Trois Rivières, included to check characteristics of the Québec urban system, is perhaps closer to the English centroid position than the Canadian, although the difference is not great.

Net Road Density

A glance at Figure 3 shows a distribution very similar to that for gross density, but with the national groups slightly further apart--the ellipses do not overlap in the net density case.

All mean densities are higher, with the average means now at 12.9 and 15.7 kms. per sq. km. for the Canadian and English cities, respectively. There are few changes in rank in terms of the means, although Saskatoon and Regina move down toward the Canadian "norm". Of the English towns, only Cambridge remains close to this Canadian centroid.

Cities in both national groups also have lower C.V.s on this indicator (Canadian and English average variations reduce from 34.8 to 25.7, and from 33.2 to 24.6). That is, when one excludes areas which are not developed, densities on the periphery are raised to a greater extent than in central areas. There is, therefore, less spatial disparity of net road density than of gross road density.

Road Junction Frequency

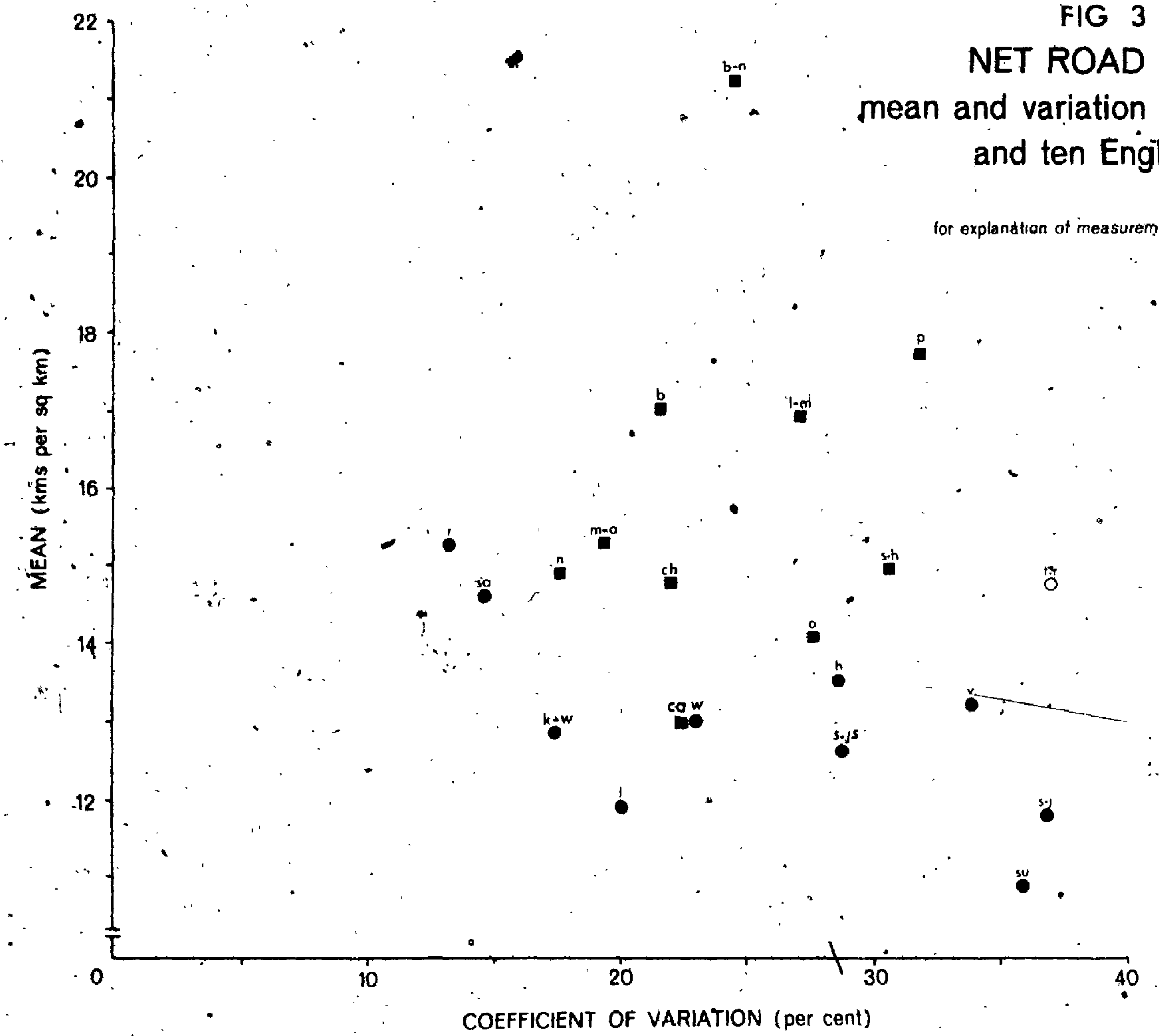
As mentioned in Chapter II, road junction frequency is largely a reflection of the scale or density of development, but it is also affected by facets of layout design. It therefore does not correspond

FIG 3

NET ROAD DENSITY

mean and variation for ten Canadian and ten English cities

for explanation of measurement procedure see text



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in all cases with the road density measure, but does show a broadly similar pattern (see Figure 4).

The national groups are quite separate in terms of mean junction frequencies. The average English mean is 5.7 junctions per km. of road, the average Canadian mean is 3.9. Canadian cities have remarkably similar means (the rotated variance for these is only 0.29), although cities with well-developed grids are perhaps slightly lower.[4]

In the English group, which is very homogeneous on this indicator, there is a high degree of correspondence with the other density measures. The older industrial towns of the north have higher means than the southern towns experiencing more recent expansion.

Trois Rivières, along with Northampton, is seen to be intermediate between the two national groupings in terms of junction density.

Road Connectivity

Junction valency is interpreted as an indicator of connectivity, and the mean is particularly affected by the presence of culs-de-sac, which have a valency of one. It is evident from Figure 5 that the sample Canadian cities contain far fewer culs-de-sac and more four-way intersections than the English group. Saskatoon and Regina in particular approach the situation of a perfect grid, which would be indicated by a mean of 4.0 and zero variation. The other Canadian cities group rather loosely around an average mean of 3.01, with

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[4]Other things being equal, a grid layout will have lower junction frequency since it has higher junction valency (connectivity).

FIG 4

ROAD JUNCTION FREQUENCY

mean and variation for ten Canadian and ten English cities

for explanation of measurement procedure see text

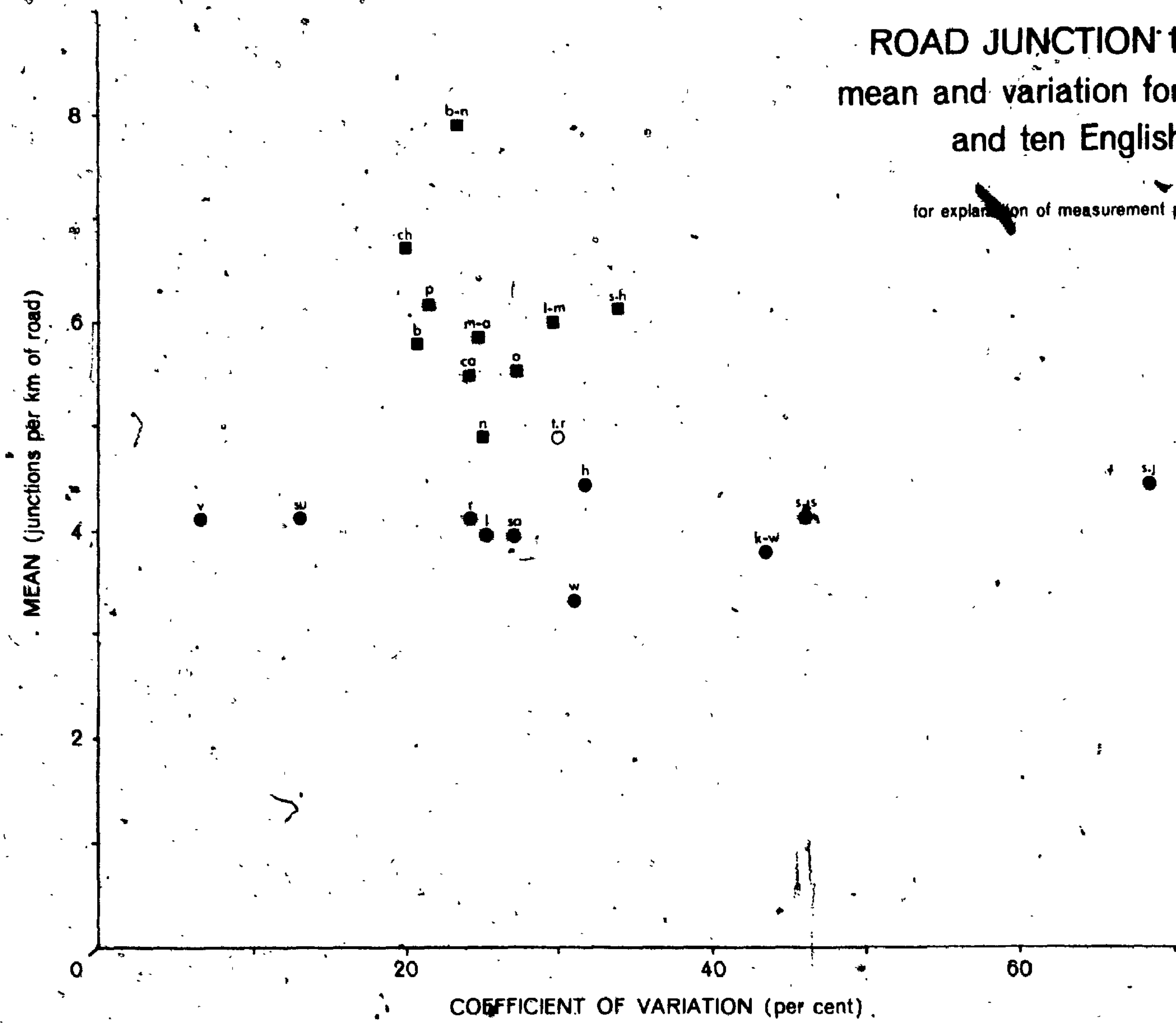

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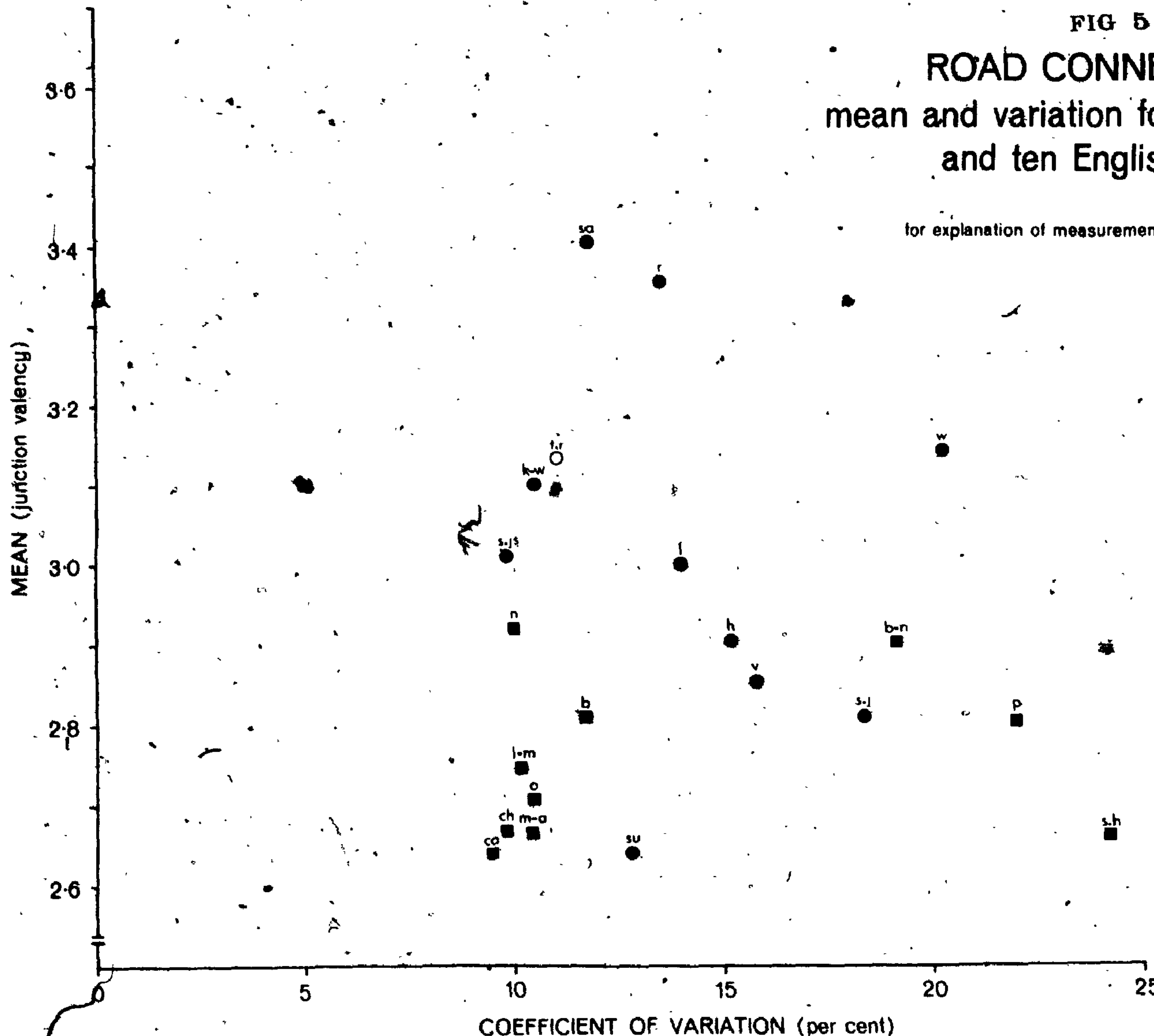
FIG 5

ROAD CONNECTIVITY

mean and variation for ten Canadian and ten English cities

for explanation of measurement procedure see text



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Sudbury showing the lowest connectivity and Windsor the greatest variation. Trois Rivières is evidently similar to the others, and has fairly well-developed grid and regular rectilinear layouts in the older town.

The English cities all have approximately the same mean--around 2.7 and 2.8--but cluster into two distinct groups with regard to degree of variation. Three early industrial Lancashire towns display much more internal variation in junction valencies than the rest, due to the presence of incipient or primitive grids in the older central areas. Since later development in these towns has been more in line with that in the rest of the country, the gridded areas contrast sharply in design (and scale), and hence the high C.V. values.

Angular Deviation at Junctions

The mean angle deviations for all the English cities and most Canadian ones lie in the range 20 to 35 percent (see Figure 6). St. John's is the only city with a very irregular pattern of intersection angles--this is partly due to topographic constraints, but more largely due to the irregularity of the pre-existing rural cadastre.[5] London, Saskatoon and Regina, on the other hand, have very few "deviant" junctions, an indication of highly-developed grid patterns.

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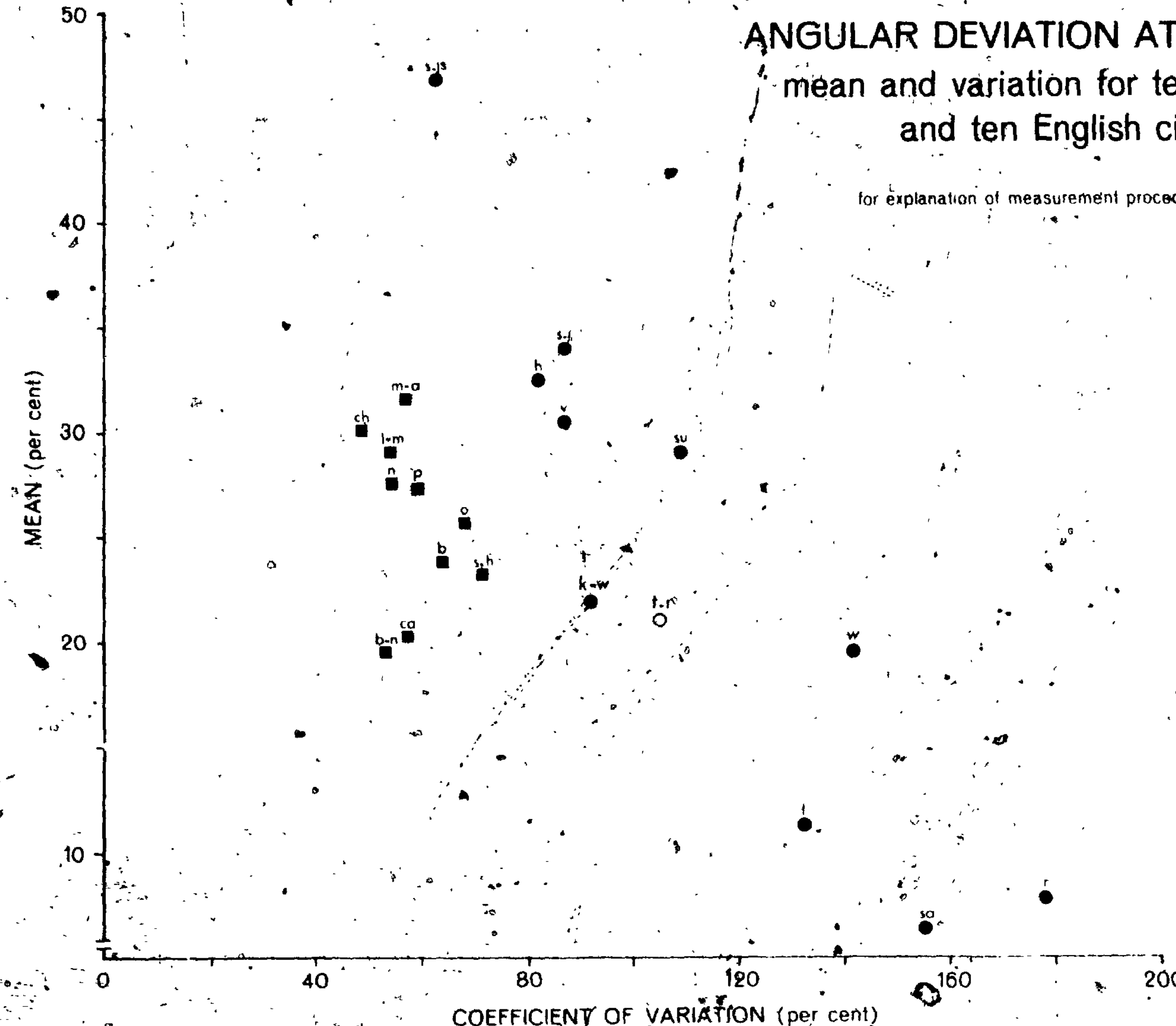
[5]The rural cadastre is an important factor in determining the shape of street layouts in all the English towns (see Ward, 1962), and is important in the Canadian cities outside the original urban survey area. By cadastral pattern is meant the pattern of property ownership, including rural roads and field boundaries. St. John's has greater angular deviation than English cities primarily because the sample area includes peripheral quadrats in which pre-existing irregular rural routes are the major elements.

FIG 6

ANGULAR DEVIATION AT JUNCTIONS

mean and variation for ten Canadian and ten English cities

for explanation of measurement procedure, see text



Very high C.V.'s are present on this measure, and these tend to increase with decreased means. This is understandable, since particularly with a grid, many $(500m)^2$ quadrats may have zero deviation, but a few may have deviations up to 80 percent.[6] In such a case, all quadrats are likely to differ greatly from the mean, producing a high coefficient of variation.

Road Curvature

As with angular deviation, and for similar reasons, the lower the mean the higher the C.V. (see Figure 7). Here, though, the English cities also seem to bear out this relationship, but with lower variation for any particular mean value. (England's curvilinear layouts are less equatable with newer development, and as most types of layout have some curved sections, there is therefore less internal variation on the measure.)

The bulk of cities in both countries have means in the order of 15 to 35 percent. The Canadian cities show a greater range of means, and for them it might be said that the higher mean values indicate earlier abandonment of grid layouts and adoption of curvilinear patterns. In terms of both curvature and angular deviation, Trois Rivières is very representative of the Canadian group.

Proportion of Land Developed in Square Km. Quadrats

Figure 8 plots the mean percentage of hectare parcels containing a building against the coefficient of variation. In general, the

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[6] High angular deviations such as this occur where there is a change in the orientation of the grid due to separate surveys. Changes in orientation affecting a smaller area often reflect early property boundaries.

FIG 7

CURVATURE :

mean and variation for ten Canadian and ten English cities

for explanation of measurement procedure see text

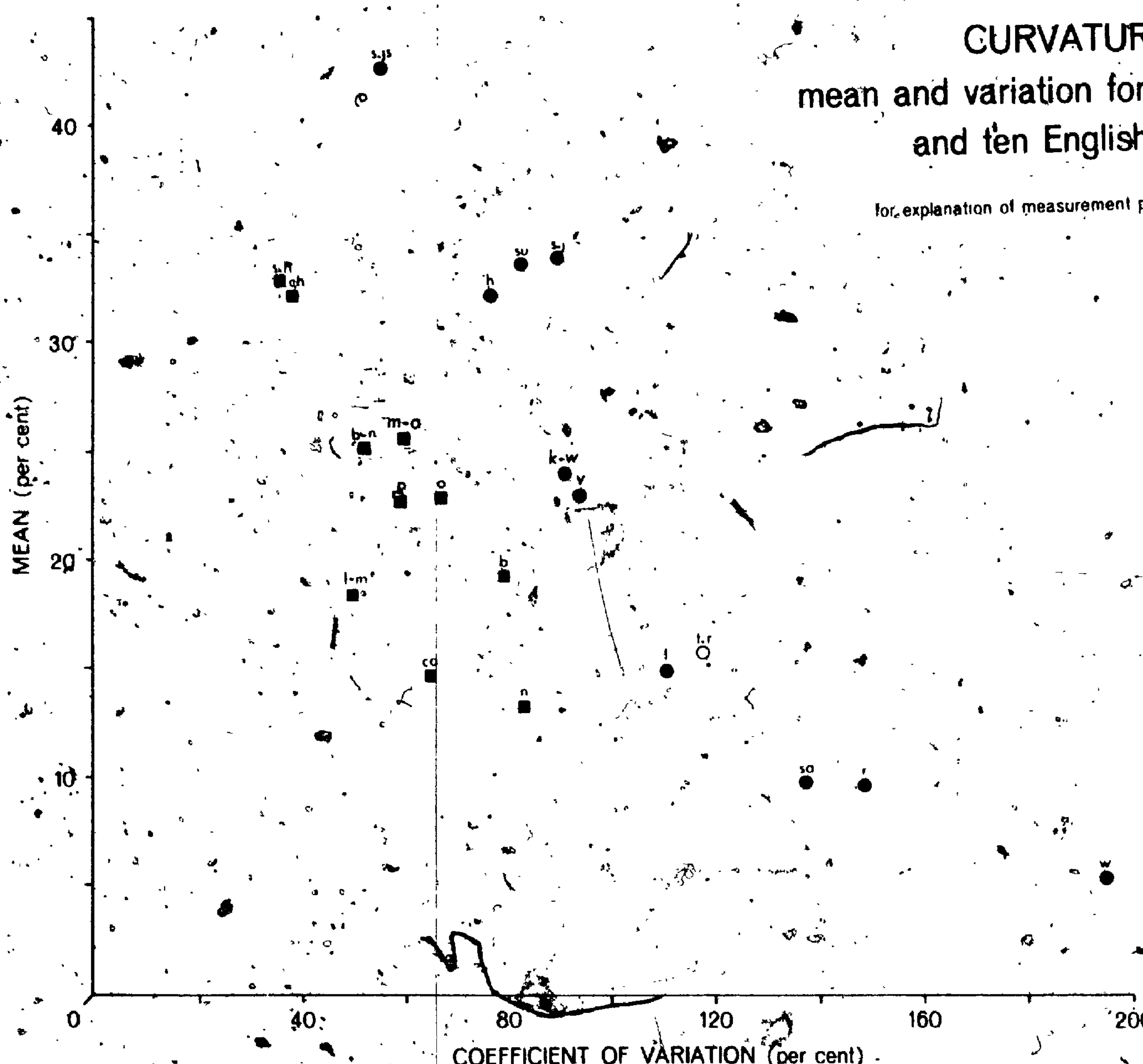
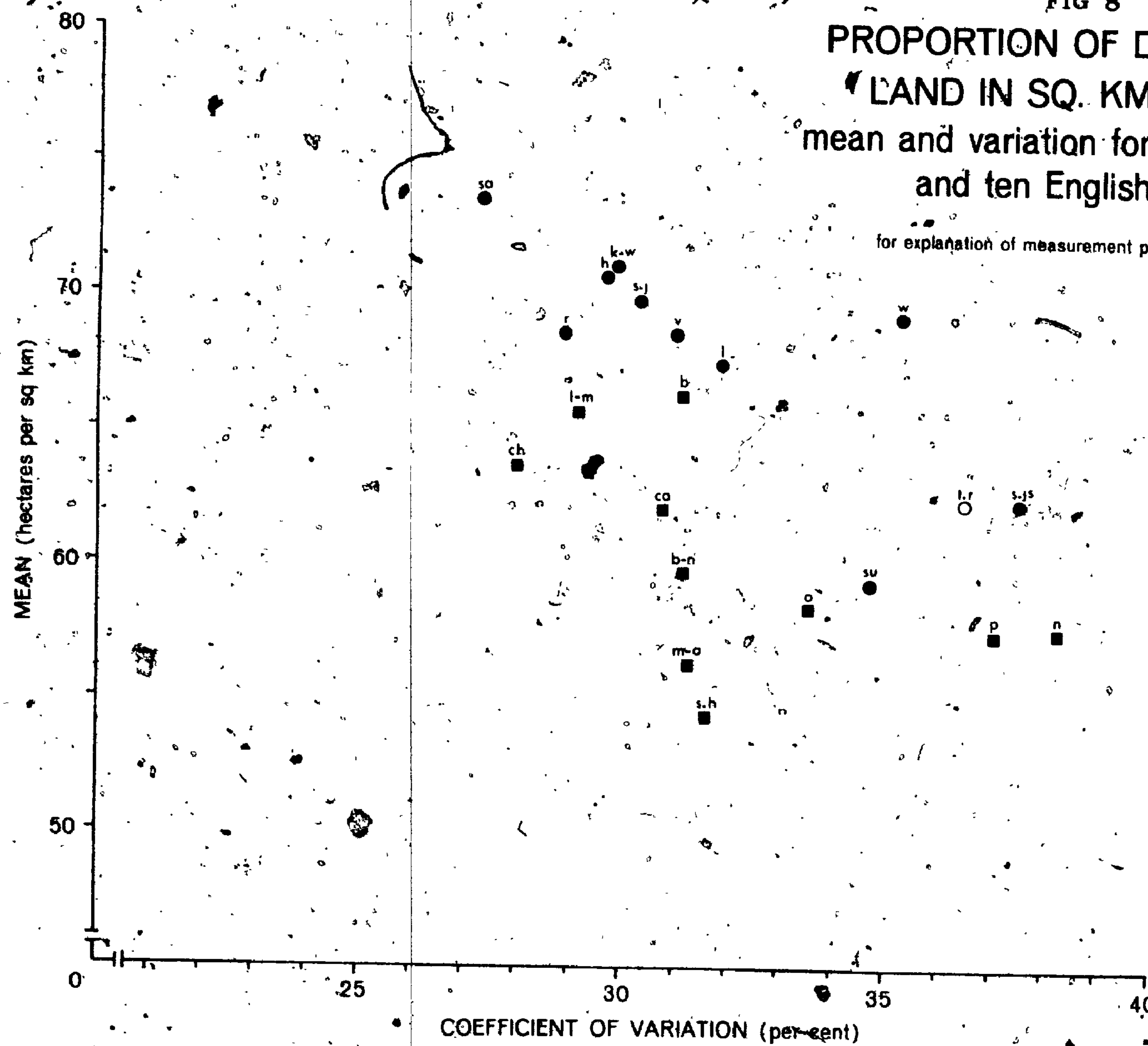


FIG 8

PROPORTION OF DEVELOPED LAND IN SQ. KM. CELLS

mean and variation for ten Canadian and ten English cities

for explanation of measurement procedure see text



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Canadian cities have considerably higher proportions developed (although the net density of developments may not be so high as in the English cities).[7] This bears out the subjective assessment that Canadian cities lack the many small open spaces evident in the English context, but instead have apportioned space into individual lots, each dominated by a building. A visual comparison of the town-plans of, say, Saskatoon and Oxford, would show the former with almost unrelieved grid development at fairly uniform density, the latter with large "wedges" and "holes" of open space use in the recent housing estates. Despite similar gross housing densities, one divides available space equally into private lots, the other sets aside large portions for shared or special uses. Aside from this difference in recent development strategies, the English cities often include "relict" open spaces in their central areas, again lowering the proportions of land developed.

St. John's and Sudbury have lower mean proportions of developed space than the other Canadian cities, largely because the topography of their sites precludes "blanket" development. The higher C.V.s suggest that, although their central areas may be as fully developed as in other cities, peripheral development is rather "piecemeal" or scattered.

The preceding descriptions should provide some sense to the graphs of composite measures of street-plan characteristics. But tests

[7] The measure only records the presence or absence of a building or buildings in each hectare parcel. Unless dwelling-unit densities are extremely low, therefore, there is no indication of net densities, but only of the degree to which the entire space is "dominated" by buildings.

of the significance of statistical differences would also be useful. Specifically, on which variables do the national groups differ significantly from each other?

A non-parametric test is required, since it is evident that there are occasionally sub-groups lying apart from the national "norms". Also, it is appropriate to test only for differences in central tendency on each of the twelve street-plan variables, since the n used hardly warrants examination of dispersion or skewness. The most powerful available test, particularly for the small populations used here, is the Kolmogorov-Smirnov two-sample test (one-tailed). For certain of the variables tested, no prior hypothesis concerning central tendency could be made, and a two-tailed test was performed instead--this indicates whether the two groups of cities differ in any respect at all.[8]

Listed below are those hypotheses which are accepted at the 99 percent and 95 percent levels of confidence.

99 percent: English cities have significantly higher means of net route density than Canadian cities.

English cities have significantly higher means of road junction frequency than Canadian cities.

Canadian cities have significantly greater variation in angular deviation than English cities.

Canadian cities have significantly greater variation in road curvature than English cities.

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[8] The reader is referred to Siegel (1956), pages 127-136, for an account of the method and critical values used. On pages 156-158 are a comparison with other tests and estimates of power efficiency, where it is noted that on small samples the K-S test has about 96 percent the efficiency of the parametric t-test, and is more powerful than either the χ^2 or Median tests.

Canadian cities have significantly higher mean proportions of land built per sq. km. than English cities.

95 percent: English cities have significantly higher means of gross road density than Canadian cities.

Canadian cities have significantly higher means of road connectivity than English cities.

The composite scores used in these tests and in the compilation of graphs are reproduced for the reader's reference in Appendix A.

2. Route Length, Built-up Area, and Population

In the sampling procedure used in this twenty-city comparison, certain measures of total urban size become available. Thus, within the delimited data areas, based as they are on the same criterion of building coverage, the total number of "built" hectares gives an indication of the area dominated by buildings, and may be interpreted as a measure of the city's physical size. It is considered useful to plot this against an estimate of population in the sample area at the sample date,[9] to detect whether the national groups show different relationships

[9] These estimates were gained by assessing the extent to which the data areas covered the developed portions of municipalities and census tracts (in the Canadian case), or wards and civil parishes (in England). In most cases, where such splitting of the census populations was necessary, the total population of the tract was only a few thousands, so that the estimate was likely to be correct to within a few hundreds. Population figures from the 1951, 1961 and 1971 censuses, with corrections for changes in tract boundaries, were used in interpolating populations at the date of survey of the topographic maps used. Since the total error in this estimating procedure was unlikely to exceed plus or minus 5,000 in any one case, estimated populations in Figure 10 are given to the nearest 10,000.

With reference to the original basis for city selection--metropolitan area population figures given by Kingsley Davis (1969)--it is obvious that functionally-based populations differ markedly from the physically-based figures computed here. This underscores the problem of urban-area definition. The Canadian 1966 and 1971 censuses list between physical and population size. Also, one may determine the total route length and total number of "built" hectares in all sampled $(500m)^2$ quadrats; again, since this one-fourth sample is selected by the same criteria in each city, these two measures may also be used as surrogates for the city's physical size. They are plotted against one another to check the strength of relationship between the two elements of morphology.

Route Length and Built Hectares

The relationship graphed in Figure 9 might be viewed as causal; as new street layouts are developed, more building development occurs--X must always precede Y. But, the two variables are part of a larger system and the relationship may more properly be seen as allometric; new streets are developed because of the requirement for more building stock, and neither groups of buildings nor road layouts are likely to occur in isolation. The graph in Figure 9 is, therefore, plotted with double logarithmic scales. Since the relationship does describe a straight line passing close to the origin, the allometric interpretation is probably most suitable, with a similar process of growth occurring in all sampled cities.

It is of note that although route length and built hectares are of different dimensionality, such that the expected exponent would be

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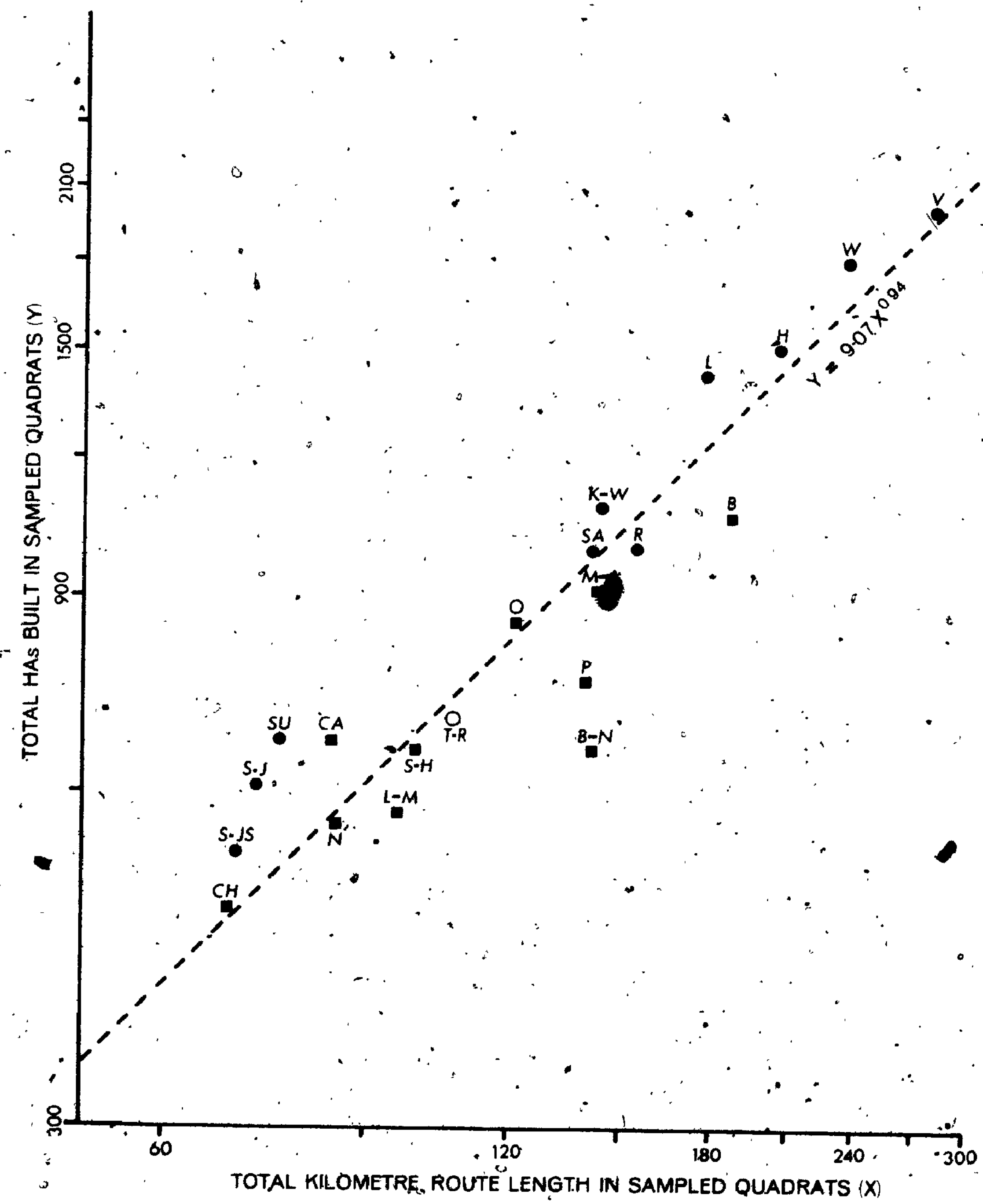
populations for metropolitan urbanized cores (rather loosely defined as continuous built-up areas covered by street pattern design and meeting a density of 1,000 persons per square mile); had comparable figures been available in the English census, this would have been preferable as a basis for city selection.

FIG 9

SAMPLED QUADRATS; TOTAL ROUTE LENGTH AGAINST BUILT HECTARES



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2.0, it is in fact 0.94. This is because in reality the dimensions are equal--typical minimum frontages remain roughly the same at whatever route density, and only plot depth varies. Thus, the underlying variables are both linear and we expect an exponent of 1.0.

The correlation between total route length and total built hectares in the $(500m)^2$ quadrats is very strong. The linear correlation coefficient for all twenty cities is 0.95, and the log.-log. coefficient is 0.93. It is, in fact, spurious to include both national groups in these estimates, as there is no a priori reason why the slopes for both should be equal. But, from visual inspection, the slope of the relationship is obviously similar in both countries, being only slightly lower in the English case. The inference here is that in English cities a given amount of road layout expansion will put less land in the developed or built-up state than in Canadian cities. This is largely true, since a given length of road will service a smaller area in England, as already indicated by gross and net route densities. However, in terms of total numbers of buildings, particularly residential units, served by a given route length, this is generally at least as great in the English case.

Built Hectares and Population

Stig Nordbeck (1971) in particular has examined the allometric relationship between area (hectares) and population of built-up areas. His method of delimiting tätorter (urban areas) in Sweden was touched on earlier in Chapter II, and is fairly comparable with the method used here. The allometric relationships he finds for approximately 1,800 tätorter in 1960 and 1965 are $A = 1.30P^{0.664}$ and $A = 1.44P^{0.650}$, respectively, where A is area in hectares and P is population. The exponent is very close to the expected value of 2/3 (P being conceptualized as three-dimensional); if the expected exponent is applied, the b-constants become 1.276 and 1.284.

Figure 10 plots population against the total number of built hectares in the data areas. Estimates of the allometric relationships with the expected exponent of 2/3 are computed from centroid positions for each national distribution. Empirical regression relationships are not found since for the Canadian case, in particular, this would be spurious; St. John, St. John's, and Sudbury happen to have particularly high densities, and Victoria particularly low, suggesting a slope not applicable to Canadian cities in general. But, in the English case, the theoretical relationship obviously approximates the regression line. It is interesting that the theoretical Canadian relationship ($A = 1.28P^{2/3}$) is almost identical to the Swedish equations.[10] The English relationship is $A = 0.122P^{2/3}$, indicating much lower space standards.

3. Principal Components Analysis of Street-Plan Variables

As a method of summarizing the aggregate measures for cities, and discerning groups of variables which represent particular design and scale types, a principal component analysis is performed for each

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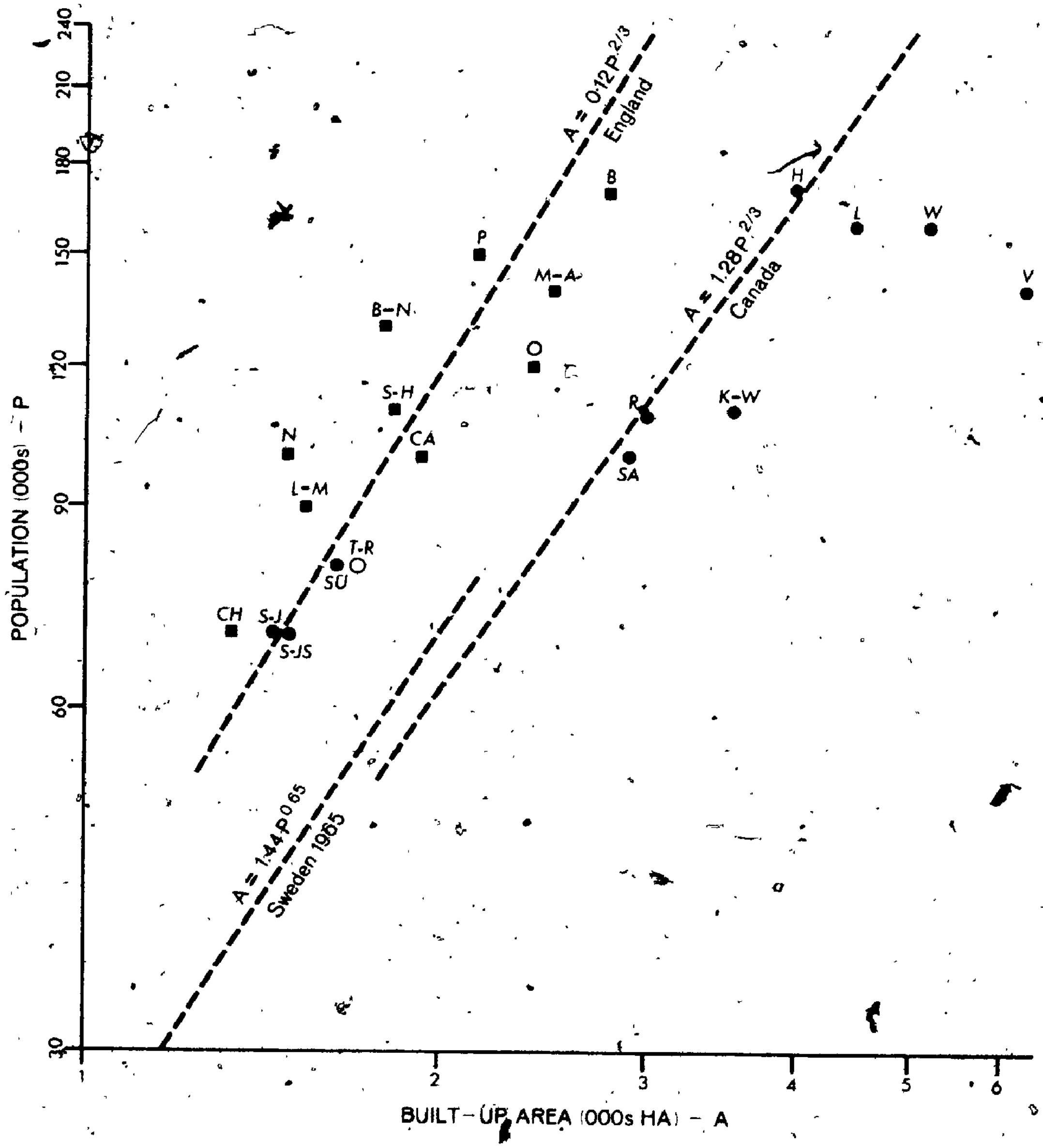
[10] A note of caution, however; Nordbeck's data were almost entirely for small urban areas below 70,000 population, and those above this figure generally had higher space standards than the equations suggest.

FIG 10

POPULATION OF DATA AREAS AGAINST BUILT HECTARES



national group separately, and for all twenty cities together. Here, only ten variables are employed, the mean and C.V. of gross road density not being included since they are less meaningful than the net density measures, and highly similar to them.

(i) Canadian Street-Plan

Simple correlation coefficients (shown in Table 2) indicate some strong relationships between the street-plan variables in the Canadian context. This suggests that certain aspects of design generally vary together.[11] Disregarding correlations between the mean and C.V. of the same descriptor (noticeable for angular deviation and curvature, and suggestive of marked spatio-temporal trends) two high correlations are noteworthy. Mean connectivity has a high inverse relationship with the C.V. of net road density (-0.91); presumably because cities such as Regina and Saskatoon have a very low variation in route density due to their uniform grid design, and also have high mean connectivity, since this is a distinctive feature of the grid system. The other high correlation is between the curvature and angular deviation measures; the means being positively correlated with r equal to 0.89. This is partly due to the fact that those cities with well-developed grids obviously have low curvature and low angular deviation, whereas topographic and historical factors necessitate high means for both in cities such as St. John's.

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[11] Note that none of the variables needs necessarily correlate highly with others, as was argued in Chapter II. This is partly validated by Table 2, where the English and Canadian coefficients often differ markedly.

TABLE 2

CORRELATION COEFFICIENTS BETWEEN AGGREGATE CITY SCORES FOR TEN VARIABLES

		Net Road Density Mean	Net Road Density C.V.	Road Junction Frequency Mean	Road Junction Frequency C.V.	Connectivity Mean	Connectivity C.V.	Angular Deviation Mean	Angular Deviation C.V.	Curvature Mean	Curvature C.V.
Net Road Density	Mean	-	-0.68 -0.20	-0.01 0.78	-0.20 -0.21	0.81 0.66	-0.16 0.48	-0.50 -0.23	0.54 -0.21	-0.51 0.17	0.39 -0.11
	C.V.		-	0.46 0.28	0.11 0.41	-0.91 -0.20	0.31 0.71	0.79 -0.20	-0.72 0.52	0.72 0.41	-0.54 -0.49
Road Junction Frequency	Mean			-	0.20 -0.15	-0.42 0.18	-0.17 0.49	0.40 -0.33	-0.42 -0.24	0.64 0.55	-0.71 -0.57
	C.V.				-	0.00 -0.27	0.07 0.29	0.34 -0.07	-0.37 0.54	0.37 0.25	-0.21 -0.33
Connectivity	Mean					-	-0.18 0.14	-0.68 -0.18	0.69 -0.26	-0.70 -0.42	0.61 0.49
	C.V.						-	-0.03 -0.36	0.13 0.42	-0.31 0.44	0.52 -0.43
Angular Deviation	Mean							-	-0.92 -0.29	0.89 0.22	-0.71 -0.07
	C.V.								-	-0.88 0.13	0.82 0.05
Curvature	Mean									-	-0.91 -0.88
	C.V.										-

NOTE: Upper figures are for correlations between the ten Canadian cities; lower figures are for correlations between the ten English cities.

Owing to the amount of intercorrelation between variables, the proportion of total variance accounted for by the first four components is high (0.95).[12] However, even after rotation, the first component (Prop. Var. approx. 0.58) is rather general; high loadings on this component are apparent for net road density (mean and C.V.), angular deviation (mean and C.V.), and mean connectivity. Inspection of the component scores suggests that this component discriminates between highly gridded and less gridded cities. The succeeding two components may be interpreted as distinguishing the degree of internal variation in layout design, since high loadings are given for the C.V.s of connectivity and junction frequency respectively. The fourth component is largely related to the mean of road junction frequency.

(ii) <u>English Street-Plan</u>

The correlations between the ten variables are generally much lower for the English sample, as may be seen in Table 2. Only three coefficients are higher than 0.7. The highest of these reflects the Canadian situation, being -0.88 between the mean and coefficient of variation of Road Curvature, and is one of the few strong relationships evident in both sets of cities. The means of net road density and road junction frequency have an understandable correlation ($r = 0.78$) since they both relate directly to the density of development. Similarly, the C.V.s of connectivity and road density ($r = 0.71$) both describe the

[12]The eigenvalue cut-off for all three component analyses was 0.7. The programme used was FACTOR, by R. T. Newkirk, Social Science Computing Centre, University of Western Ontario. This employs varimax rotation. For all three component analyses, factor loadings are listed in Appendix F.

degree of internal variation within cities. Note that two pairs of variables show much less covariation than in the Canadian case; the means of curvature and angular deviation (0.22 versus 0.79), and the mean and C.V. of angular deviation (-0.29 versus -0.68).

Owing to the generally lower correlations between variables, the first four English components account for less variance (0.91) than the Canadian ones, and are quite different in composition and interpretation. The first explains approximately 37 percent of variance and is less general than in the Canadian analysis, with particularly heavy loadings (0.91 and -0.96) for the mean and C.V. of curvature. The loading for mean junction frequency is less important (0.69). Inspection of component scores shows this component discriminates between the older industrial towns of the Lancashire type and the more modern towns of the south.

The means of net road density and connectivity load highly on the second component, and the scores for this serve to isolate Burnley-Nelson and Preston as very high density, somewhat gridded, industrial towns (component scores of 5.56 and 2.28; except for Blackpool all other scores are negative).

The third component seems to identify the degree of internal variation within cities, with heavy loadings for the C.V.s of angular deviation (-0.86), junction frequency (-0.76), road density (-0.73), and connectivity (-0.62). St. Helens shows up clearly as the town with most internal differentiation of street-plan characteristics, with a component score of -5.98.

The final component for the English sample is largely related to the mean of angular deviation, which has a loading of 0.96. Owing largely to its historical grid characteristics, Burnley-Nelson is particularly distinguishable on this component with a score of -2.71.

(iii) Combined Street-Plan

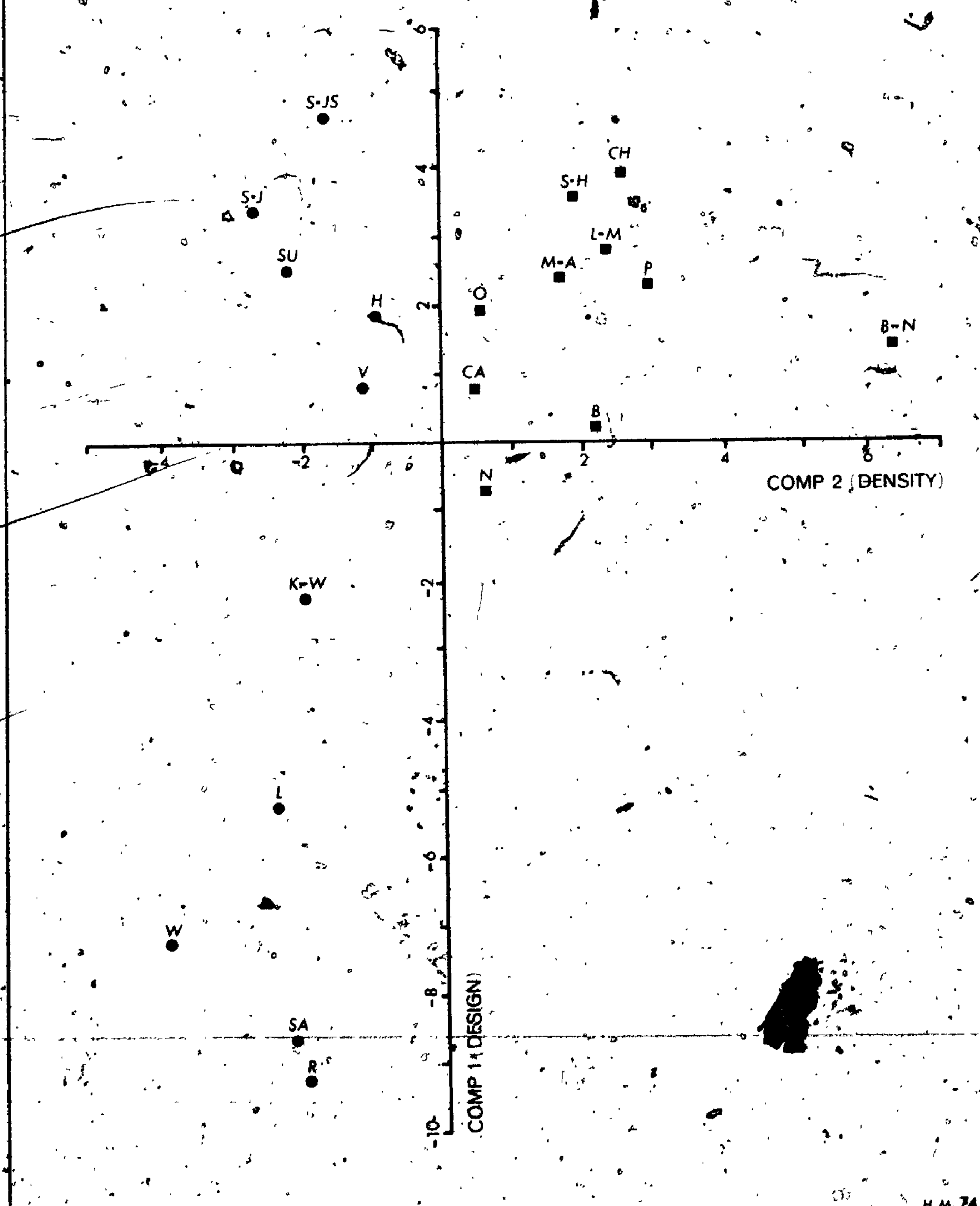
The correlation matrix for the combined set of twenty cities has coefficients somewhat intermediate between those for the national sets individually. Again, there is a negative correlation between the mean and C.V. of curvature (-0.70). Positive correlations occur between the means of curvature and angular deviation (0.79), between the C.V.s of curvature and angular deviation (0.79), and between the means of the two density indicators, road density and junction frequency (0.80).

If between-group variation is greater than within-group variation, one would expect a simpler component structure for the combined group, such that the components are easily identifiable and the scores clearly differentiate between the national sets. This is largely the case. The first four components account for 93 percent of total variance and component one may clearly be labelled as discriminating aspects of design; high loadings are given for mean connectivity (-0.86), and for angular deviation (mean 0.86, C.V. -0.80) and curvature (mean 0.83, C.V. -0.80). The only density or scale element associated with this component is the coefficient of variation of road density (loading of 0.79), but this also loads quite heavily on component three.

All but one of the English cities (Northampton) have positive component scores on this design component (see Figure 11). Those

FIG 11

COMPOSITE STREET–PLAN MEASURES;
COMPONENT SCORES FOR FIRST TWO PRINCIPAL COMPONENTS



Canadian cities scoring positively (St. John's, St. John, Sudbury, Halifax, and Victoria, in descending order) may be assumed to be the most similar to English cities in terms of average street layout design and internal variation of design. The most negative scores on this component were those for Regina (-9.3) and Saskatoon (-8.7)--both highly gridded and uniform cities. Transitional are Windsor (-7.1), London (-4.6), and Kitchener-Waterloo (-2.2).

Component two is easily identified. It relates to scale factors, with high loadings for mean road density (0.94) and mean junction frequency (0.87). In Figure 11, it is noticeable that this component distinguishes exactly between the higher-density English cities with positive scores and the lower density Canadian cities with negative scores. These scores are perhaps of greater significance than those for component one since, in terms of townscape perception, density or scale may be a more important or noticeable factor than the particulars of layout design.

Since the first two components account for approximately 70 percent of total variance, it is reasonable to view Figure 11 as describing the relative positions of the cities in a ten-variable space--it suggests the current degree of diversity of composite street-plan forms in Canada and England. Canadian cities show a greater range with regard to design aspects, but slightly less diversity in terms of scale. The eccentric position of Burnley-Nelson relative to the English group is noteworthy.

The third and fourth components are almost exclusively related to aspects of internal variation; respectively, they have high loadings for the C.V.s of connectivity (0.96) and road junction frequency (0.90).

To sum up regarding this section, principal components analysis has been used as a method for detecting underlying groups of street-plan variables, to aid description of intra- and inter-national differences. The component structures of both national groups individually are less easily identifiable than for the twenty cities taken together. International differences are, therefore, more evident than those within each country.

4. Hierarchical Grouping of Cities

The density ellipses in Figures 2 to 7 hinted at groupings of cities in variable-space, and this has been further investigated in the graph of component scores on major components of street-plan (Figure 11). To extend this appreciation of within-group and between-group differences, and of proximities in variable-space, an hierarchical grouping procedure is performed.

The algorithm employed (Ward, 1963) successively groups cities to minimize within-group sums of squares.[13] Cities were grouped on twelve variables (that is, including the gross road density measures) since this adds more discriminating power. It also weights road density in accord with our assessment of its importance vis-à-vis the design measures.

[13] The method starts with t separate taxonomic units, and groups them successively into t-1, t-2, ..., 1 taxa (groups), computing at each stage an "objective" function, which is some measure of the desirability of the particular arrangement of the t units, into k < t taxa at any one stage. The objective function here is the potential within-group sum of squares divided by the potential N of the group. The programme employed is a modified version of HGROUP (Veldman, 1967).

The grouping results are shown by a dendogram (see Figure 12). The pair of cities with greatest similarity is Saskatoon and Regina. Three pairs of English cities are also very similar--Mansfield-Ashfield and Chesterfield, Oxford and Cambridge, and Blackpool and Lancaster-Morecambe. These latter three pairs eventually link up, along with Northampton, to form the major sub-group of the English sample. The three towns most associated with the industrial revolution form a less coherent sub-group. Among the Canadian cities the amount of information lost in grouping is generally larger, and at the level of error where the English form only two groups, the Canadian cities form four.

One would expect that after the penultimate grouping there would be two groups each comprising all the cities of one country. In fact, the Canadian group which may be identified as less gridded joins with the English cities rather than with the five more gridded Canadian cities. However, the error term at this stage is very large in comparison with earlier groupings.

Certain cities do not combine with others until the later stages, and these may be viewed as relatively unique within the sample. Examples are Burnley-Nelson, St. John and St. John's, and Windsor.

The most "natural" number of groups for a typology would be four, since the error term drops off rapidly after this point, from 16.5 to 27.3. The four groups may be identified as:

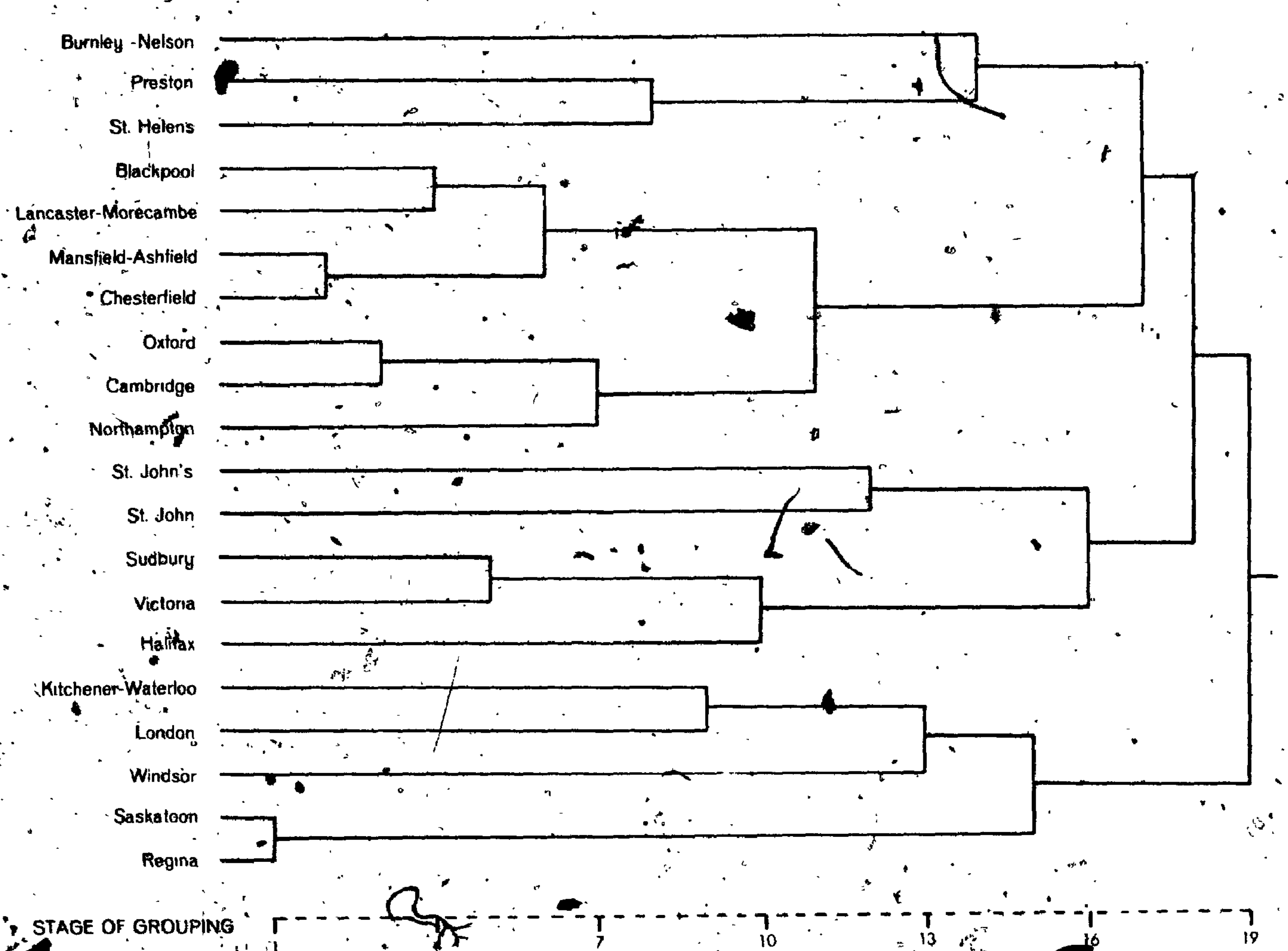
(a) the five gridded Canadian cities,

(b) the five imperfectly-gridded Canadian cities,

(c) the three early-industrial English towns, and

(d) the remaining seven English towns.

FIG 12 HEIRARCHICAL GROUPING BY STREET-PLAN VARIABLES; DENDOGRAM



5. Summary

To review briefly the content of this chapter, twenty cities have been described in terms of current differences and similarities with respect to their street-plans taken as a whole. This is of course useful, since it is the degree of homology of cities as composite entities which is relevant to perceptions and behaviours at any one time. That is, even if areas of new development in cities of the two countries were exactly similar, this would have implications more for the future than for the present, if major portions of their urban areas still presented great dissimilarities inherited from the past.

In the data presented here, it is interesting to note the relative similarity of English street-plans as compared with the more varied Canadian set. English cities appear to possess less internal variation on most measures, and also the amount of this variation is more uniform within the group; there is greater similarity at both the intra-city and inter-city levels. The two sets of cities differ most with respect to net road density, road junction frequency, and the irregularity of junction angles, but there is some overlap between them on nearly all measures used. Principal Components analysis suggests that the national groups are differentiated particularly by scale factors, rather than by aspects of design.

Such results are useful in pointing out distinctive elements of each country's townscapes. The descriptive measures and sampling procedures used could be utilized in investigating a number of research problems. One interesting possibility is the identification of distinctive or abnormal urban regions, either within a nation or within individual cities.

Also, were similar data collected for a number of countries, some intriguing hypotheses on the influences of proximity, empire, trade, and migration, would surely be suggested.

The thrust of this dissertation, however, is to discern whether there has been a process of homogenization, occurring over time. The following chapter approaches this problem for the twenty sample cities.

CHAPTER IV

SPATIO-TEMPORAL TRENDS IN STREET-PLAN FEATURES--TWENTY CITIES

I. The Distance Surrogate

In this chapter, reliance is placed on the use of position relative to the city centre as a surrogate for the time of development of street layouts. It would obviously be preferable to place an approximate date on the layout in each $(500m)^2$ quadrat through the use of archival materials, but to do this for twenty cities with any degree of precision would prove an enormous task. However, this type of detailed survey will be conducted later for two representative cities.

Urban incremental development generally takes place at the periphery of the built-up area, and theories of urban structure and growth explicitly suggest a succession of concentric rings of growth from the city centre outwards.[1] The period of development will correlate more highly with distance from the city centre in larger

[1]Thus, the classic concentric circle or zonal model of Ernest W. Burgess (1923) assumed growth and radial expansion to be primarily determined by distance from the centre, although distorting factors such as site and physical barriers were also recognized. Reasons for this pattern of development have been advanced in terms of land economics (see Alonso, 1960, and Yeates, 1965). Chapin and Weiss (1962) assume the distance variable to be so important in determining the location of new developments as to structure their analysis on deviations from the expected pattern based on a "circular normal template." The relationship, however, is not particularly strong at the micro-scale of analysis, and seems to have declined through time (Millward, 1972).

cities, and particularly in laissez-faire land market situations. Johnston (1969) feels the relation is strong enough to use concentric zones as direct indicators of time of development in his model of house-style diffusion in Melbourne. The reader is referred to Chapter V, Section 3, for some empirical evidence on the validity of this surrogate measure for street layout development.

The surrogate is particularly valid if the rate of population increase, and the population density of developments, are both constant through time. As an illustration of this point, assume a city growing at twenty percent every ten years from a population of 10,000 in 1800, and at a constant density of 5,000 per km^2. If increments are always at the periphery of concentric circles, then the circle of radius one km. would contain all pre-1829 development, that limited by radius two kms. pre-1905, three kms. 1950, and four kms. 1981. Although the added area increases with each circle, the range of development vintage within each decreases, in this example from 76 to 45 to 31 years (see Footnote 2). This is useful, since an analysis using circles of constant radius increase provides us with greater discernment of the most recent trends.

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[2] Some figures for this illustrative example may be useful:

	Radius in kms. 1	2	3	4
Area enclosed (km^2)	3.41	13.65	30.69	54.56
Added area (km^2)	3.41	10.24	17.04	23.87
Constant Density example:				
- date radius reached	1829	1905	1950	1981
- population at date (000's)	17	68	154	272
Reduced Density example:				
- date radius reached	1829	1903	1931	1955
- population at date (000's)	17	66	108	168

If development densities decrease through time (the case historically), then the range decreases even further. In the example given here, if densities are 5,000 per km^2 prior to 1900 and 2,500 per km^2 after that date, then the periods encompassed by the one-kilometre wide zones are 74, 28, and 24 years long, respectively (Footnote 2).

However, the sample cities do not have the same physical extent, partly because of different population sizes, partly because of varying densities. Therefore, it would be quite fallacious to use circles of similar interval width as comparative devices. This size differential is circumvented by varying the interval between zones in relation to the outward spread of development in each delimited study area; the standard deviation around the mean distance of $(500m)^2$ quadrats from each city centre[3] is used as the interval width. For example, if the mean distance is 4.0 kms. and the standard deviation is 2.0 kms., then the city may be partitioned into zones defined by radii of 2.0; 4.0, 6.0, and 8.0 kms. A constraint is added to ensure that all such zones include at least four quadrats; for instance, if only two quadrats lie beyond 8.0 kms., these are assigned to the fourth zone out, which then includes all development beyond 6.0 kms. Using these operational guidelines, all twenty cities are described by just four rings of development, each containing at least four quadrats. There is still

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[3]Some of the sample cities comprise two major centres in a twin-city arrangement. These are Kitchener-Waterloo, Burnley-Nelson, Mansfield-Ashfield, and Lancaster-Morecambe. In these cases, distance from the centre was measured to the nearest town centre, so that there are, in fact, two overlapping sets of concentric circles. Implicit assumptions of this method are the approximately similar size and history of growth rates of the twin centres, least true for Kitchener-Waterloo.

not true comparability, owing to varying growth rates and densities,[4] but in general zones two, three and four are all composed of developments built this century, and zones three and four encompass generally inter-war and post-war development, respectively.

Aside from the generalized description of temporal trends afforded by this concentric-zone breakdown, it should be noted that the method allows quite an objective description of spatial trends within each city. That is, it gives a concise description of the changing character of street layouts as one moves from the city centre out to the periphery, and therefore provides further evidence concerning the degree of diversity within each composite street-plan.

2. Graphical Representation of Trends--Six Street-Plan Indicators

In contrast to the analysis in the preceding chapter, this section will deal only with the means of the six plan indicators in each concentric ring, and make no comment regarding degrees of variation within these zones (since sample sizes are often too low). The means are graphed and joined by smoothed curves suggesting the spatio-temporal trend in each city. In Figures 13 to 18, the Canadian curves may be compared with the English ones, and the mean or average curves for each country are also indicated.

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[4] It could be argued, for instance, that since the English cities generally originated much earlier than the Ca[illegible] set, one would not be comparing developments of comparable age [illegible]entral zone, thus in part pre-determining convergence results. But the pre-nineteenth century cores of the English towns seldom occupy more than a small fraction of the central zones. As Smailes (1955, 99) suggests, "geographers should recognize the extent to which towns as we know them are products of the quite recent past."

In terms of the notion of morphological convergence, the graphs may be viewed in several ways. To illustrate, if average road density in England goes from twenty kms. per km^2 in zone one to ten in zone four, whilst it changes in Canada from ten to five, the difference between the two decreases in absolute terms (from ten to five), but remains the same in relative terms (that is, English roads continue to be twice the density of Canadian roads). Do we, then, measure changes in the degree of difference between places in absolute or in relative terms? According to the introductory discussion of the homogenization concept, absolute difference may be the critical indicator; but, in terms of human perceptions, might not relative differences be equally as important? There is no easy answer, of course, and the writer proposes to skirt around this rhetorical question by suggesting that if both absolute and relative convergence is evident, there is little doubt concerning the operation of an homogenization process. And even if there is a decrease in only one respect, greater uniformity is suggested.[5]

Gross Road Density

One expects measures of gross density to decline with distance from the city centre, since the further out one goes the more land is still available for development and infilling.[6] For gross road density,

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[5]Of course, even if there are both absolute and relative increases in the difference, one might still suspect the operation of a shared influence if the overall trend in both countries (or cities) is in the same direction (for example, if net road densities in both areas begin to decrease at the same time).

[6]The varying nature of this distance decline relationship (particularly for population density) has been investigated in

this distance decline gradient is evident in both Canadian and English cities. In Figure 13, one notes that the English cities possess considerably more dense street systems in their historical cores, but that towards the newer peripheries densities have declined almost to the Canadian level. The group averages (Table 3) decline quite smoothly, for the English cities from 17.6 km. per km^2 to 10.9, as compared with 14.8 to 8.5 in the Canadian case. Thus, the absolute difference between these two averages in zones one and four declines -37 percent (Table 4), suggesting convergence or homogenization. In relative terms, however, the English density is initially twenty-six percent greater than the Canadian average, and increases to twenty-eight percent greater in zone four. Therefore, relative difference increases plus two percent.

Regarding variation within the two countries, both sets appear to follow parallel paths of development, and to display approximately the same degree of within-group variation through time-space. Possibly, though, the Canadian group of cities has become slightly more diverse, as in their central areas they are remarkably similar in gross density (with the notable exception of St. John's).

Net Road Density

Although naturally higher throughout, figures on net density are very similar to those for the gross measure, except for the

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detail. It is a very predictable result of spotty development at the urban periphery. See Clark (1951), Tanner (1961), Berry, Simmons, and Tennant (1963), and Newling (1969). The type of density used in these studies is more "gross" than the usual definition of gross density, but is analogous to the measure used here.

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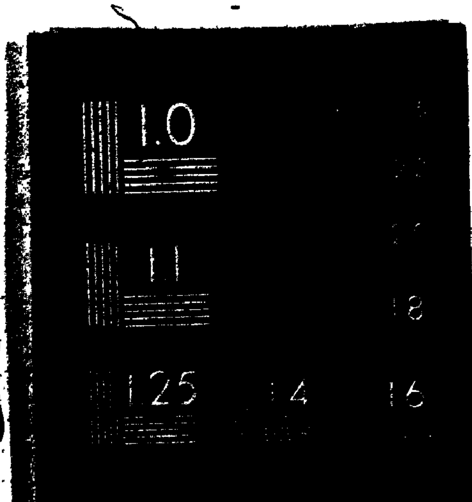

FIG 13

zonal trends in gross road density

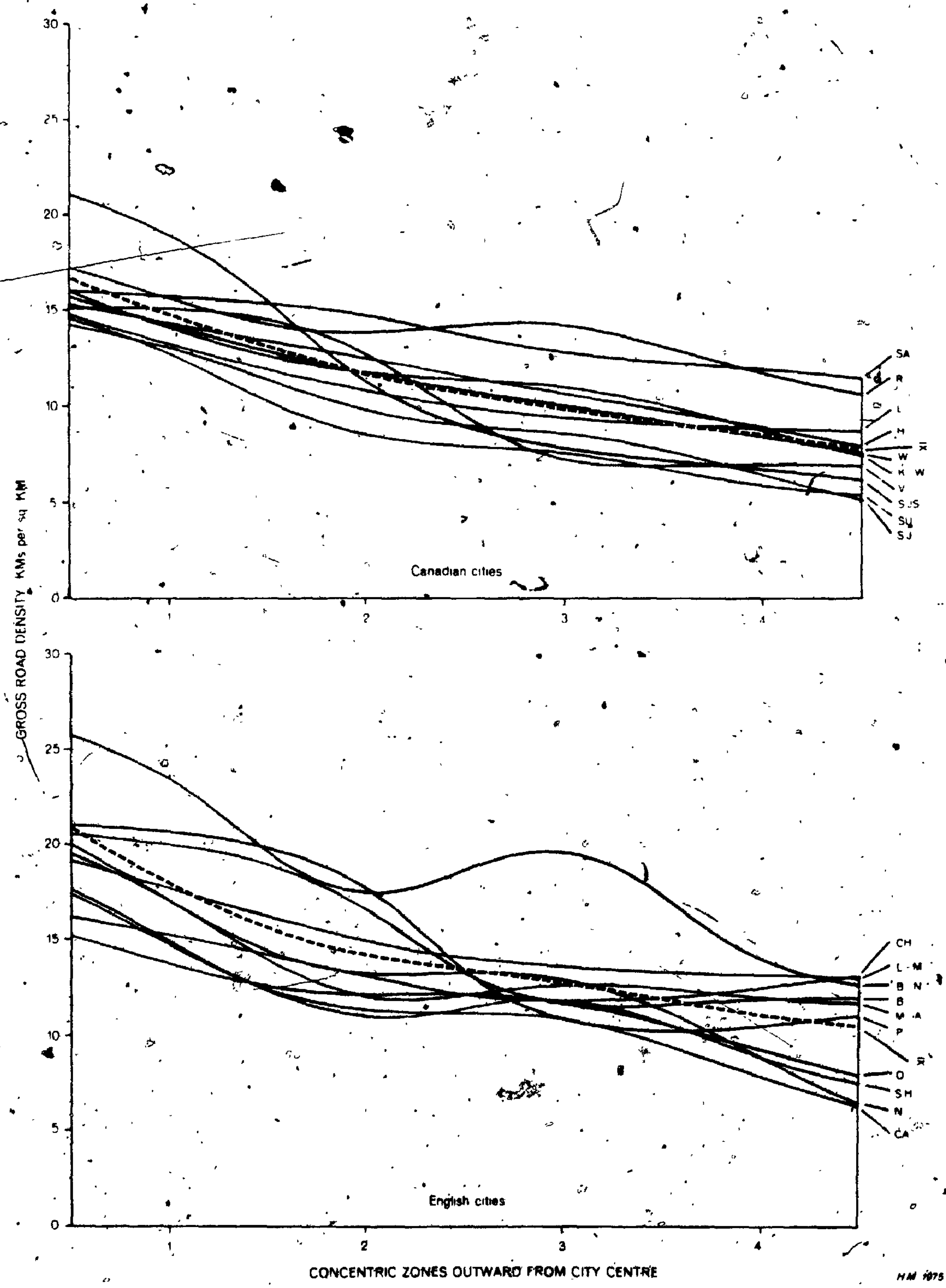

TABLE 3

AVERAGE SPATIO-TEMPORAL DATA

	Zone Number	Gross Road Density (kms per km^2)	Net Road Density (kms per km^2)	Road Junction Frequency (jctn per km)	Connectivity	Angular Deviation (percent)	Curvature (percent)	Distinguishing Features*
Average of Canadian City Means	1	14.8	15.3	4.62	3.32	17.5	13.7	Grid Rectilinear
	2	11.9	13.4	4.27	3.02	23.4	20.5	-
	3	10.0	12.0	3.71	2.89	22.9	23.3	-
	4	8.5	11.8	3.52	2.82	30.5	32.6	Irregular Curvilinear
Average of English City Means	1	17.6	18.8	7.00	2.92	26.6	23.8	High Density
	2	14.1	16.4	5.93	2.81	24.8	21.5	-
	3	12.8	15.1	5.66	2.73	25.4	23.9	-
	4	10.9	14.0	5.79	2.61	25.2	24.3	Cul-de-Sac

*See typology, Chapter II, Section 4.

TABLE 4

SPATIO-TEMPORAL CHANGE IN THE ABSOLUTE AND RELATIVE DIFFERENCES BETWEEN NATIONAL AVERAGES--SIX VARIABLES

	ABSOLUTE DIFFERENCES				RELATIVE DIFFERENCES		
	Inner Zone	Outer Zone	Change	Relative Change (%)	Inner Zone (%)	Outer Zone (%)	Change (%)
Gross Road Density	3.8	2.4	-1.4	-37	26	28	+2
Net Road Density	3.5	2.2	-1.3	-37	23	20	-3
Junction Frequency	2.38	2.27	-0.11	- 5	52	64	+12
Road Connectivity	0.40	0.20	-0.20	-50	14	8	-6
Angular Deviation	9.1	5.3	-3.8	-42	52	21	-31
Road Curvature	10.1	8.3	-1.8	-18	74	34	-40
Average				-31.5			-11

A negative change indicates convergence.

important difference that the decline is much less on the periphery, and in a number of ~~cities actually~~ reverses to an increase in density[7] (Figure 14). Again, the English road densities decline towards those evident in Canadian cities, and the gap between average densities narrows from 3.5 to 2.2 kms. per km^2, or minus thirty-seven percent. Even in relative terms, the English road densities are only twenty percent higher on the periphery versus twenty-three percent higher in the centre (Table 4). Similar density declines through time are explicable largely in terms of technology (the automobile and its access requirements) and increased prosperity and consumer demand for land. Stabilization of this trend probably reflects increases in the relative cost of land. Such increases are due both to planning controls and to the consolidation of speculative property holdings.

Note that these net density measures are not fully comparable with the circulation ratios provided by Caminos et al. (1969), since they do not include footpaths and other non-vehicular access.

Road Junction Frequency

Levels of this measure are higher throughout in the English cities (Figure 15), but decline from around 7.0 junctions per km. of road down to 5.7, increasing slightly again in recent development. Except for St. John's, the decline is less marked in Canada, since lower road densities are offset by decreases in connectivity (Table 3). The absolute difference between the national averages decreases slightly

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[7] This stabilization or increase in net density at the periphery compares with similar findings on net population density by Berry and Horton (1970, 296).

FIG 14

zonal trends in net road density

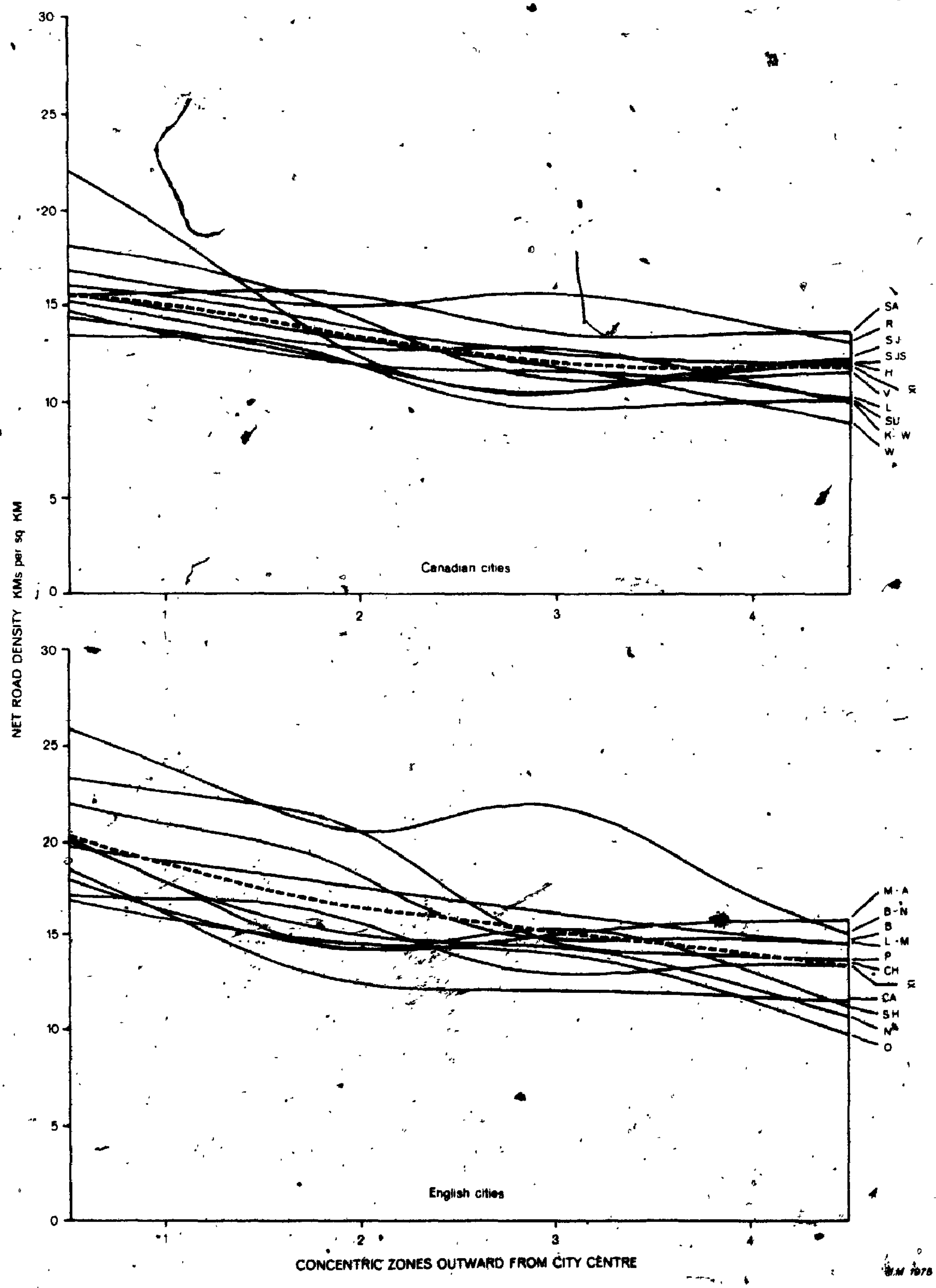
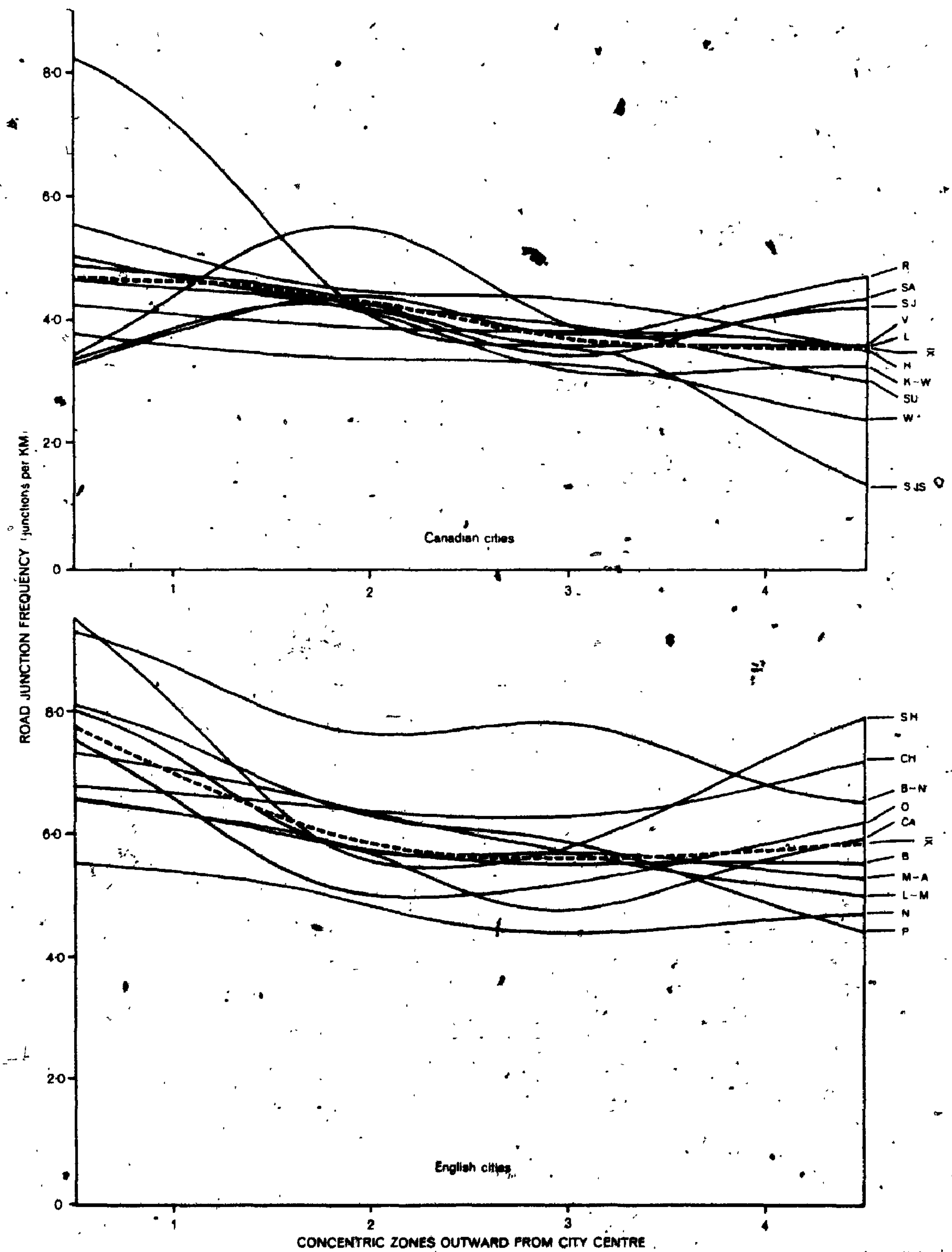


FIG 15

zonal trends in junction frequency



through space-time, minus five percent from zone one to zone four. But, in relative terms, the English average jumps from 152 to 164 percent of the Canadian, a divergence of twelve percent (Table 4). Thus, this aspect of street-plan seems to have been less subject to international homogenization than road densities.

Internal variation is less in the Canadian group, but there seems to be a recent divergence at the periphery (this is perhaps not true for net junction frequency, however).

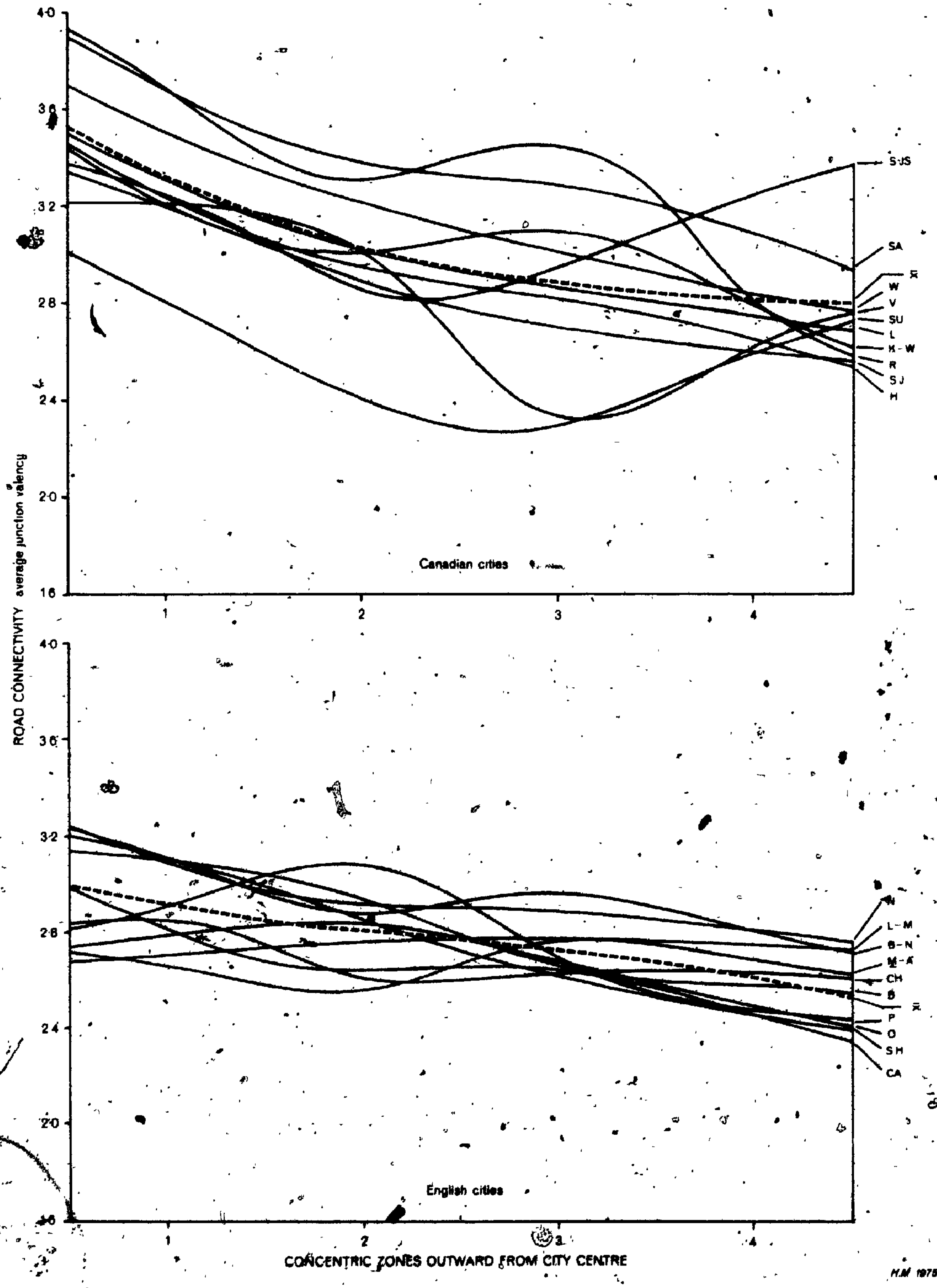
Road Connectivity

As Canadian cities have outgrown their original gridiron surveys, new development has increasingly been characterized by T-junctions rather than four-way intersections. Connectivity measures, therefore, decrease through time-space toward the rather constant English level (Figure 16). The Canadian cities are characterized by initially greater variation as a result of varying surveys, but show definite convergence on similar peripheral values. Perhaps because of the small sample size in this zone (n = 4), St. John's is again a deviant case. The English cities remain remarkably similar to each other through time-space, with little variation around the group average.

Homogenization between the national groups is more evident for this design indicator than for the preceding density measures. Absolute difference declines fifty percent and relative differences six percent (see Table 4). Note that whereas English cities move toward the Canadian precedent in terms of density, Canadian cities seem to follow the English example in terms of this design feature.

FIG 16

zonal trends in connectivity



Angular Deviation at Junctions

As with road connectivity, it is again the Canadian group which changes through time to approach and even surpass the angular deviation evident in the English cities (Figure 17). It is hardly surprising that there should be this increase, since all the Canadian cities contain a planned core, and right-angle junctions are a hallmark of planned layouts (as discussed in Chapter II). But this being so, one would also expect fewer deviations from the 90° norm in recent developments on the periphery. Five of the Canadian cities, and four of the English towns, bear this out; for the rest, the angular deviations in zone four are somewhat misleading, since they often reflect the presence of pre-existing irregular rural routes (in the case of St. John's, for example), or changes in the alignment of the original land surveys (for example, Windsor). Since we are really concerned only with the form of road layouts within development sites, one might question the suitability of the sampling procedure for this measure.

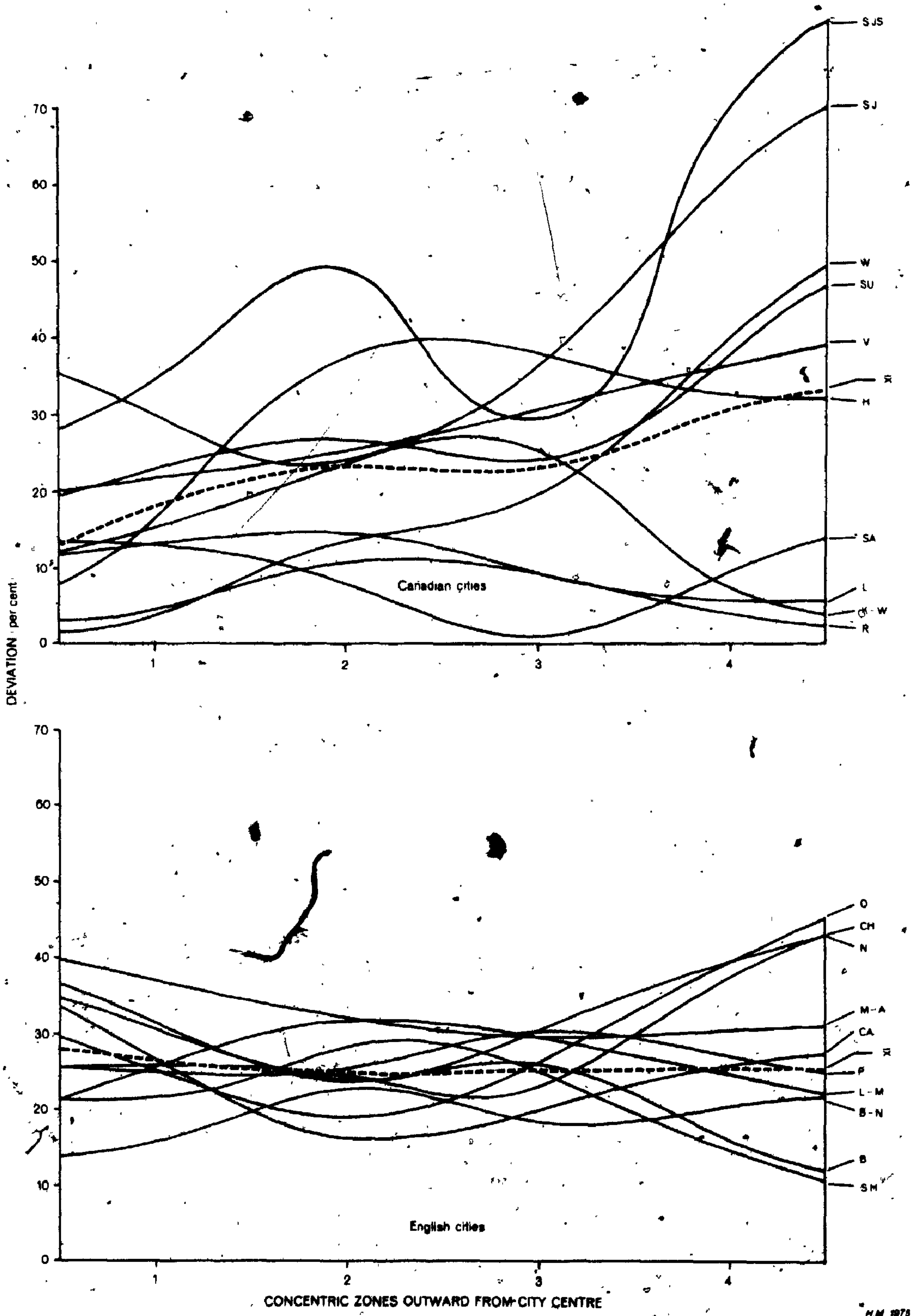
Bearing in mind these difficulties of interpretation, however, between-national differences in angular deviation decrease forty-two percent. Relatively, the English value is fifty-two percent higher than the Canadian in zone one, whilst the Canadian is only twenty-one percent higher in zone four. Thus, again there is both absolute and relative convergence.

Road Curvature

As the Canadian cities have expanded beyond their original gridiron surveys, curvilinear layouts have increasingly been adopted as an element in site plans. In the English towns, curved street sections

FIG 17

zonal trends in angular deviation



have always been part of the townscape. Figure 18 reflects this. But why does it also show peripheral development in some Canadian cities to be considerably more curvilinear than in the English case? Several answers are possible; for one, curvilinear layouts may have been rediscovered independently in North American (and in a sense they were); or, there may have been an overreaction to rectilinear systems since they were associated with the discredited gridiron plan. Again, however, figures for zone four should be viewed with caution, since particularly in St. John and St. John's, they partly reflect the presence of winding rural roads recently incorporated into the built-up area.

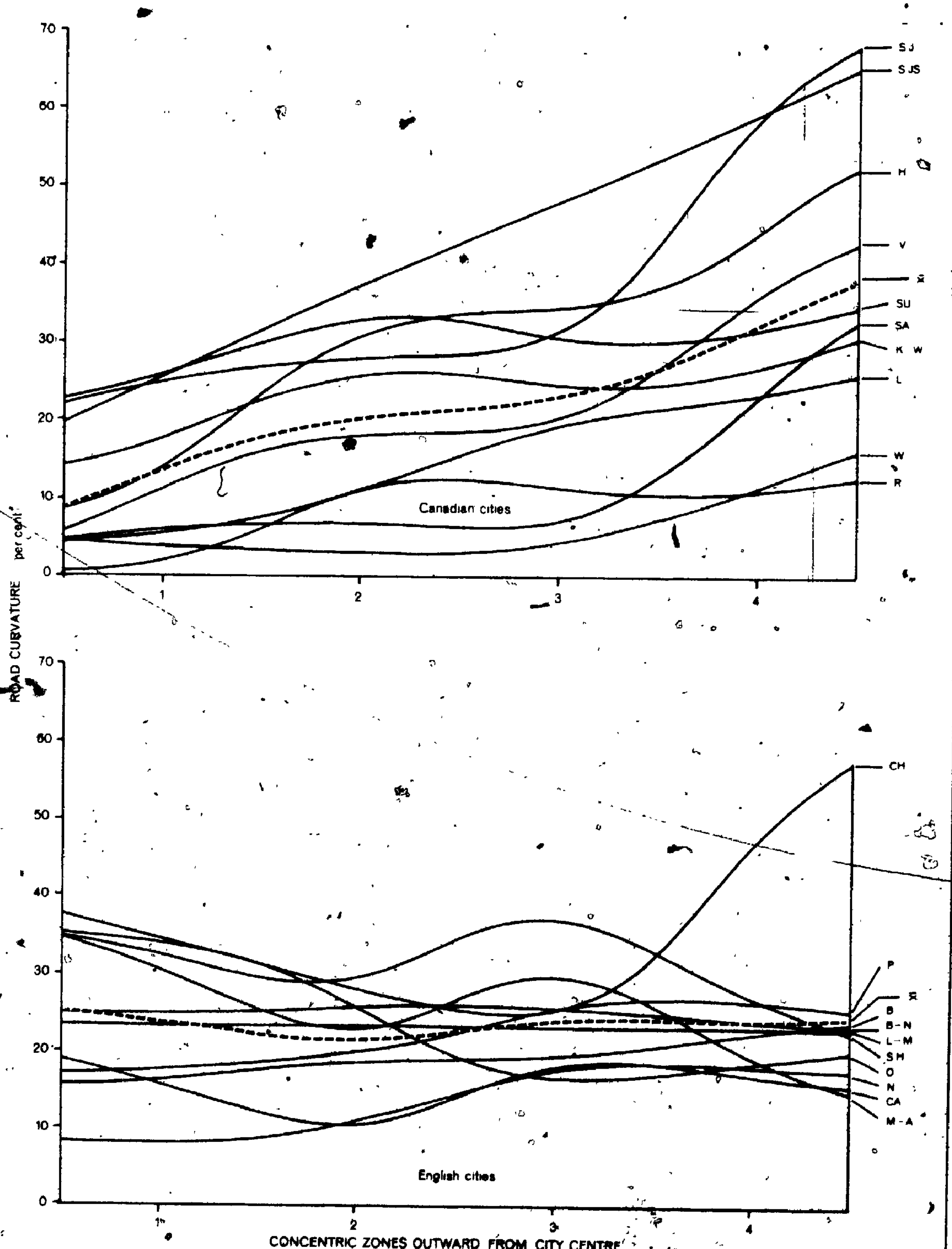
It is evident that within-nation variation is greatest and apparently increasing for the Canadian group, much less and decreasing for the English group. In the latter, only Chesterfield appears anomolous in zone four. Concerning average differences between the two national groups, the absolute gap falls eighteen percent, and the relative difference declines forty percent, the largest amount for the six street-plan indicators.

The results of this spatio-temporal analysis seem to suggest that street-plans developed in successive periods are increasingly similar between the two countries. Convergence within the national sets is much less evident, however, largely because there is little within-nation variation initially.

Perhaps the most important point emerging from the figures is the marked distinction in trends between density and design features.

FIG 18

zonal trends in road curvature



Thus, the Canadian cities maintain rather constant densities throughout, whilst the English cities move progressively towards the Canadian level. In contrast, the Canadian cities seem to move towards the steady English levels in terms of design (connectivity, angular deviation, and curvature). The English lag in density standards results from lags in automobile ownership ratios and consumer income standards. As these have increased, space demands[8] have more closely approximated North American levels. Changes in Canadian design features result more from the diffusion of fashionable planning criteria, often emanating from Europe or inspired by European practice. The changes are, therefore, in the direction of the English levels.

3. Trends in Overall Disparities

The spatio-temporal graphs allow examination of trends for each street-plan indicator separately. But, it would also be useful to assess the degree to which the plan forms as a whole exhibit convergence or homogenization through space-time. One may approach this problem through the use of distance measures in variable space.

The hierarchical grouping procedure used in Chapter III gave such a measure at each stage in grouping. This error index at each

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[8]The model presented in Chapter I assumes that effective demand is catered for by developers, insofar as the rather faulty market mechanism allows. But, one should bear in mind the large public housing sector in Britain, providing rental accommodation for approximately twenty-eight percent of households (Cullingworth, 1973, 43), and responsible for developing half of all new units since the war (Clawson and Hall, 1973, 86). This sector is much slower to reflect the costs of land and housing in relation to personal incomes, and in fact operates via a bureaucratically-operated allocative structure rather than through market competition (see Paris, 1974).

stage was computed as the sum of the squared differences between variable scores, divided by the number of cities in the new group. To weight each variable equally, scores were standardized. This method is not appropriate in examining sequential sets of data, however (as in the space-time zones examined above), since the standardization would not be computed from the whole set of scores for each variable, but only from the set for each zone. Thus, each variable would be transformed to portray approximately the same degree of variation in each zone, and discernment of increasing similarity would not be possible.

What is required is a measure of similarity (or variable-distance) between city pairs, which is comparable between zones. One possibility is to use a distance metric based on the standard deviations of each variable for all scores in all zones.

That is,

$$D_{ij}^{m} = \frac{1}{n} \sqrt{\sum_{k=1}^{n} \frac{(x_i^{km} - x_j^{km})^2}{\sigma_k^2}}$$

where i and j are two cities,

n = the number of street-plan variables

m = the zone number

σ_k^2 = the variance for all scores of variable k.

The coefficient D would express pythagorean distances in variable-space, in units of averaged standard deviation.[9] It is,

---

[9]This coefficient obeys the four axioms given by Sneath and Sokal. None of the coefficients reviewed in their work will allow the same comparability through successive sets of data (see Sneath and Sokal, 1973, 121-128).

however, rather difficult to interpret such units, and it was felt preferable to express degrees of difference relative to a theoretical maximum disparity, as a percentage. That is, with reference to the maximum observed range on each variable, rather than to its central tendency. This disparity index is given as

$$P_{ij}^{m} = \frac{100}{n} \sum_{k=1}^{n} \cdot \frac{|x_i^{km} - x_j^{km}|}{x^k MAX - x^k MIN}$$

where x^kMAX and x^kMIN are the maximum and minimum values of variable k in the whole set of scores. The maximum possible disparity index between two cities in any time-space zone is, therefore, 100 percent.[10]

One could compute complete ten-by-ten matrices of P-indices for each zone, but for the purpose of discerning within- and between-nation similarity through time, it is sufficient to compute indices only with respect to the national centroids[11] for each zone. For within-nation

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[10]As an example, if there is one variable k, two zones m and p, and three cities, h, i and j, then scores of

30_h^m, 20_i^m, 10_j^m, and 20_h^p, 10_i^p, 5_j^p, would give

P_{ij}^m = forty percent, P_{ij}^p = twenty percent.

The maximum and minimum values used are as follows:

Gross Road Density:	max = 23.4, min = 5.8 kms per km^2.
Net Road Density:	max = 23.7, min = 9.6 kms per km^2.
Road Junction Frequency:	max = 8.9, min = 1.2 junctions per km.
Connectivity:	max = 3.70, min = 2.46.
Angular Deviation:	max = 70.7, min = 1.0 percent.
Curvature:	max = 59.5, min = 1.9 percent.

[11]The centroid for each zone is defined as "the point in phenetic space whose coordinates are the mean values of each character over the given cluster of OTUs" (Sneath and Sokal, 1973, 195). That is, the centre of gravity of the cluster. Its variable values do not therefore coincide with those for a particular city. The city lying nearest in variable-space to the centroid (in this case, with the lowest P-index vis-à-vis the centroid) is termed the centrotype.

homogenization, one expects the disparity between members of each national group and its centroid to decrease in successive zones. Homogenization between national groups should be indicated by decreasing disparity between the two centroids, as well as decreasing disparity between each set of cities and the centroid of the other nation.

Table 5 lists P-indices, vis-à-vis the two centroids, calculated for each city and each zone. Note that these are generally very low, compared with the theoretical maximum disparity of 100 percent. For purposes of discussion, they can be summarized as follows:

AVERAGE DISPARITIES WITH CENTROIDS, PER GROUP

	Zone 1 Centroids		Zone 2 Centroids		Zone 3 Centroids		Zone 4 Centroids	
	CAN	ENG	CAN	ENG	CAN	ENG	CAN	ENG
Average P for Canadian cities (%)	11.6	24.4	11.2	19.2	12.7	21.3	14.7	22.6
Average P for English cities (%)	24.2	12.3	15.8	10.6	15.8	8.1	18.7	10.3

Thus, on average, the Canadian cities lie slightly closer to the Canadian centroid in zone one (average P = 11.6 percent) than do the English cities relative to the English centroid (12.3 percent). Progressing through the zones, however, the average Canadian disparity increases overall, suggesting increasing diversity within the nation. In contrast, average English disparities fall as low as eight percent, with an overall decrease despite a slight rise in zone four. The English group, therefore, appears to become more cohesive through time.

TABLE 5

OVERALL DISPARITIES BETWEEN CITY INDICATORS AND NATIONAL CENTROIDS
(P-INDICES PER ZONE, MAX = 100%, MIN = 0%)

	S.J.	S.JS	SU	SA	R	V	H	W	L	K-W	L-M	S.H.	CA	N	B-N	OX	CH	M-A	B	P
ZONE 1																				
Canadian Cent.	12	24	16	10	16	7	4	12	9	7	28	19	15	15	36	22	24	31	23	31
English Cent.	27	8	21	31	37	20	22	36	23	21	4	16	12	13	22	14	10	10	11	12
ZONE 2																				
Canadian Cent.	10	15	17	18	14	4	10	12	9	3	20	11	15	9	26	9	18	14	16	21
English Cent.	14	23	23	22	19	12	16	26	22	16	6	10	16	10	15	9	8	11	8	14
ZONE 3																				
Canadian Cent.	12	16	12	20	23	12	11	9	6	7	14	19	9	9	34	13	15	16	15	15
English Cent.	19	29	20	26	24	21	16	23	19	17	3	7	12	8	25	6	8	4	4	5
ZONE 4																				
Canadian Cent.	22	28	10	19	21	8	9	12	12	9	18	22	17	10	25	17	23	19	22	15
English Cent.	30	45	21	17	16	19	17	24	18	19	8	12	11	15	13	11	15	8	6	6

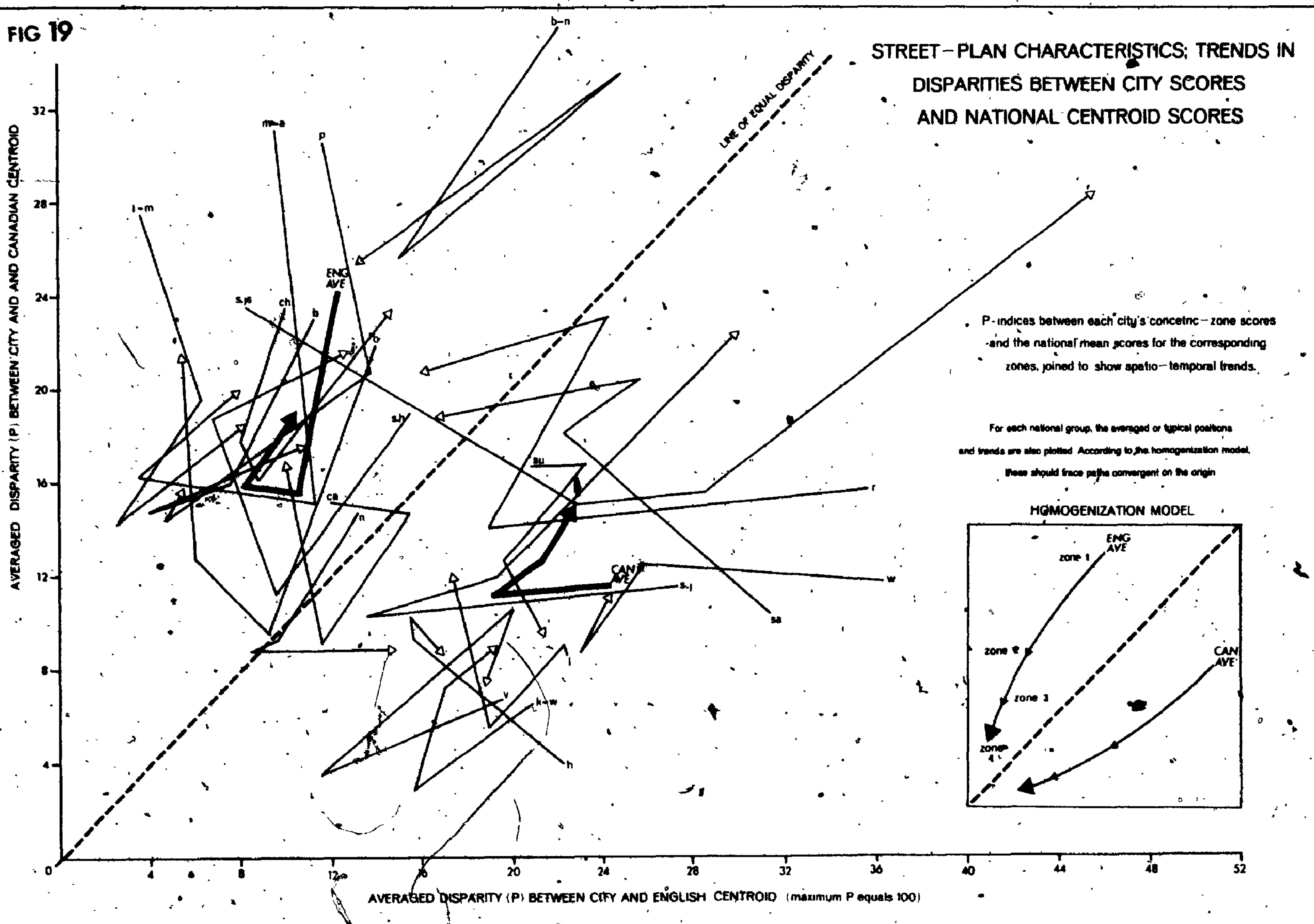
In zone one, Canadian cities are on average twice as removed from the English centroid as from the Canadian centroid (24.2 versus 11.6). But the disparity with the English centroid declines overall to 18.7 percent. This suggests convergence between the two nations, and the trend is confirmed somewhat by the average disparity between English cities and the Canadian centroid. This declines overall from 24.2 in zone one to 18.7 in zone four. More important, the disparity between the two centroids (themselves moving through variable-space) changes from 24.5 percent in zone one, to 11.8, 14.0 and 17.3 in zone four. Overall, there is increasing similarity, but in the peripheral zones there appears to have been some divergence.

This reversed trend is portrayed graphically in Figure 19, which plots P-indices of each city with respect to the two national centroids, for the four zones (using the figures in Table 5). Increasing homogenization would be represented by two groups of paths converging on the origin, as in the inset. The average paths bear this out initially, but then the Canadian cities in particular move away from both centroids. This does not accord with the expectation of convergence, and we must conclude either that the sampling design is inappropriate to the investigation of very recent trends, or that plan convergence has in fact recently given way to form divergence.

Regarding the first possibility, one should note that for certain Canadian cities design and density measures for the peripheral zone are quite distorted by small sample sizes and the criterion by which the sample quadrats were selected. By taking $(500m)^2$ units with large numbers of "built" hectares, the intent was to screen out

FIG 19

STREET–PLAN CHARACTERISTICS; TRENDS IN DISPARITIES BETWEEN CITY SCORES AND NATIONAL CENTROID SCORES



pre-existing rural elements and bias the sample towards fully-developed urban sites. This was least fully achieved in St. John's and St. John, and consequently these two cities score low road density measures and unusually high angular deviation and curvature measures in their peripheral zones, reflecting dispersed linear settlement along rural roads. This distorts the position of the Canadian centroid for this zone and consequently all P-indices relative to it.

But the absence of continued convergence in the final zone cannot be attributed solely to difficulties in the sampling procedure. Obviously, the further apart groups of cities lie in variable space, the greater the opportunity for convergence, and the more rapid will absolute convergence be. Thus, between zones one and two, the English cities, on average, move rapidly towards the Canadian centroid (Figure 1), reducing disparities by almost forty percent. But, as was suggested earlier,[12] we logically expect rapid form-convergence only to the point where extrinsic factors are similar, and thereafter convergence is likely only with increasing similarities in broad intrinsic constraints. Without increased similarity in constraints such as prosperity levels and land pressures, one expects only that new site developments will follow parallel paths in variable space, and that, in terms of the disparity measure used here, P-indices will remain roughly constant through time.

[12]See Chapter I, Section 2, regarding the logistic curve of disparities through time.

4. Summary

Through the use of distance from the city centre as a surrogate for the time of development of street layouts, this chapter has outlined temporal trends in the design of such layouts in the twenty sample cities. Average trends for each nation were analyzed with respect to absolute and relative differences on each plan indicator, both of which are decreasing for the majority of indicators. An important distinction can be made between the trends for design and density variables: the Canadian cities become increasingly similar to steady English levels of road curvature, "deviant" junction angles, and street connectivity, whilst the English cities display most change in densities, declining toward fairly constant Canadian levels.

Taking all variables into account, however, measures of overall disparity suggest that the national groups are presently diverging in their form characteristics, becoming less cohesive internally and displaying less between-group similarity. Results in the following two chapters, pertaining to the "true" temporal trends in two representative cities, will also show a recent slackening in between-nation convergence, but will contradict the suggestion of divergence. The author concludes that, while the P-indices undoubtedly reflect reduced rates of convergence attributable to contrasting sets of intrinsic constraints operative on the development markets, due to difficulties in the sampling procedure one should be cautious of accepting them as evidence for recent divergence.

CHAPTER V

TEMPORAL TRENDS IN STREET-PLAN DESIGN--TWO CITIES

The following two chapters constitute an analysis of the changing nature of plan features through time, using evidence from archival and large-scale map sources for two representative cities. Continuing to focus on street layouts, this chapter attempts to discern "true" temporal trends in their design and density, which may then be compared with the trends suggested by use of the distance surrogate. Although obviously one should be cautious of ascribing contrasts and trends in the two cities to generally-operative national factors, nevertheless the detailed information gained from this approach will at least be highly indicative.

Particularly during this century, development sites in both countries have increased in scale and, in cities of the size being considered, may extend over a square kilometre or more of land. Thus, it is generally possible to fix a small period of time during which the majority of streets in any 25-hectare quadrat were laid out. In the two representative cities, each quadrat will therefore be assigned a date, so that the nature of street design and density in each of several historical periods may be examined. Particular attention will be paid to developments occurring during the last decade.

1. Choice of Example Cities

The earlier analysis of aggregated data for twenty cities may be used as a basis for selecting two cities which typify the national groups; that is, which display the essential or common characteristics of each group. But several sets of data have been presented which complicate the selection of centrotypes. At the most aggregate level one may use figures relating to the composite urban form, and rank cities by their distance from national centroids for each indicator (as shown in Figures 2 to 7). But, to be truly representative, the example cities should be similar to the national means not simply for each indicator, but for each indicator in each concentric zone. Thus, the P-indices given in Table 5 may also be used as a basis for selection.

Obviously, no city is likely to constitute the centrotype for all plan indicators in all zones. Looking first at the Canadian group, however, several cities consistently cluster near the national mean, whilst others--St. John's, St. John, Saskatoon and Regina--repeatedly lie far from it. London is by far the most representative in terms of rankings by distance from the centroids for composite scores (average rank for all indicators equals 2.5), followed by Halifax (3.8), Kitchener-Waterloo (4.8), and Windsor (4.8). However, if one similarly ranks cities according to the zonal disparity indices given in Table 5, the lowest average ranking is for Kitchener-Waterloo (1.7), followed by Victoria (2.5), Halifax (2.7), and London (3.7). The two sets of rankings suggest three good candidates--Halifax,[1] London, and

[1] Halifax, however, was not included in the most "Canadian" group by the hierarchical grouping procedure (see Figure 12).

Kitchener-Waterloo. A final choice among these three was made almost solely on the basis of the author's familiarity with the City of London, and the ready availability of archival and current plans of this city.

Among the English group of cities, there are again several which might be taken as representative. Ranking the cities by the deviations of their composite scores from the national means for each indicator (that is, using the information summarized in Figures 2 to 7), Lancaster-Morecambe (average rank 3.8), Mansfield-Ashfield (4.0), Oxford (4.0), and Blackpool (4.2) may be viewed as most typical of the group. Looking at zonal disparities from the national centroids (Table 5), average rank position is lowest for Lancaster-Morecambe (1.5), Blackpool (2.3), Mansfield-Ashfield (3.5), and Preston (4.5). Lancaster-Morecambe therefore appears most characteristic on both sets of scores, with Mansfield-Ashfield and Blackpool being almost as useful. All three of these grouped together in Figure 12 to form a core group of English cities. Referring back to Table 1, however, the estimated population of the data area for Lancaster-Morecambe is only 90,000 (as compared with 160,000 for London). The built-up area, therefore, may not contain sufficient samples of developments in a series of time-periods to maintain comparability with London (that is, the scale of developments in some periods is unlikely to fit the $(500m)^2$ quadrat size used in this study). Of the other two possibilities, Mansfield-Ashfield was chosen as the representative English city, since the author is more familiar with it, and planning documents and studies could be more easily secured for this area.

Both London and Mansfield-Ashfield are free-standing urban areas having fairly similar population sizes during much of the last 150 years.[2] In both, layout designs and density are little affected by peculiarities of local topography and site conditions.[3] Mansfield-Ashfield, in Nottinghamshire, is an urban agglomerate consisting of several historically-distinct towns and villages, but in terms of the development market and development controls these function as one unit, subject to one planning authority. During the period since effective development and subdivision controls were instituted in London, the Ontario city has been overbounded and also subject to uniform planning controls.

In terms of characteristics of the structural environment, general census information suggests both cities reflect the national situations very closely. Thus, by breakdown into market sectors, single-family dwelling structures in all Canadian cities are 78.8 percent owner-occupied, and 21.2 percent rented; the figures for London are 81.0 and 19.0 percent (1971 Census). By type of dwelling unit,

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[2]During the middle and late nineteenth century, London possessed a considerably larger population than Mansfield-Ashfield. From about 1890 through to 1930, however, the English urban area grew very rapidly through expansion of coal-mining activity, and it was not until about 1950 that London's built-up area again equalled the population of Mansfield-Ashfield. Since that date, the Canadian city has rapidly outstripped the English centre's population size.

[3]There is, however, one distinctive effect of local geology on urban form in Mansfield-Ashfield--owing to subsidence from continued working of coal seams beneath the built-up area, no high-rise flats were built during the period of their vogue in the 1960's. Other English cities of similar size typically possess ten to twenty ten-storey tower blocks.

figures for urban Canada are 51.5 percent single-detached, 7.7 percent single-attached, and 40.8 percent apartments, whilst those for London are 54.8, 8.2, and 37.5, respectively. In England and Wales, there are three major market sectors. Mansfield-Ashfield and national percentages in these sectors are very similar, being 41.9 and 43.4, respectively, for owner-occupation, 27.4 and 24.1 for local authority rental, and 23.6 versus 22.6 for private rental.[4]

In terms of the range of housing quality, census figures (1971) giving the distributions of dwelling-value show London to possess a range similar to the Canadian urban average, but of somewhat higher value (median of \$21,502 versus \$21,214). Another indicator of quality, number of rooms per dwelling (1961) shows Mansfield-Ashfield almost exactly equal to the national norm, although with slightly less spread either side of the five-room mode.

Both cities have experienced population and structural growth rates through time which are very comparable with overall national rates. A great majority of residential structures have been developed during this century in both areas. In London, over sixty percent of all dwellings are of post-1945 vintage (as compared with the national urban figure of sixty-five percent), whilst the Mansfield-Ashfield figure is approximately forty percent. The greatest expansion in housing stock in the English city took place between the wars, which is consistent with the general English experience (see Cullingworth,

[4]Figures for 1961. By 1968 the national distribution had shifted to approximately fifty-two percent owner-occupation, twenty-eight percent local authority, and twenty percent private rental (Clawson and Hall, 1973, 134).

1960, 50). Both example cities, however, display a number of housing developments in each of several time-periods, which makes it possible to conduct a temporal analysis of their plan forms.

2. Historical Development of the Street-Plans

For each example city, the date of construction of each presently-existing street section was estimated from archival maps and plans. Particularly in London, the distinction between date of construction and date of planning is important, since much of the grid within the nineteenth century city limits was planned and surveyed at one time. It would, of course, be very useful to examine the dates of plan design for all separate layouts, but this information is not always available, and plans may be modified several times before final construction.

A time-series of plans was assembled for each urban area, and the coincidence of dates between these series partly determined the time-periods to be used for analysis. However, some attempt was also made to ensure that these periods validly approximated eras of urban development. In England, the two World Wars constitute important dividing lines, since municipal housing becomes important after World War I, and urban planning has strong effects after World War II. There is also an important transition in England in the years following 1875, particularly with regard to densities and scale of development.[5] In

[5]Primarily owing to the introduction of model by-law housing following the 1875 Public Health Act. For an example of this legislation's effects, see the analysis of by-law housing in Hull by Forster (1968). Gayler (1970) uses the years 1880 and 1890 as benchmarks in his reconstruction of housing development in S.E. Essex.

Canada, the World Wars also mark important breaks in market conditions, whilst a transition around 1875-1880 is particularly evident in London, as by this time the original city grid plan is almost completely developed.

The periods used were, therefore, defined as pre-1880, 1880-1920, 1920-1950, and post-1950. Since this study is primarily concerned with recent trends, the post-war period was further divided into two twelve-year periods--1950 to 1962 and 1962 to 1974.[6] Sufficient information was available for estimation of development during all periods with a minimum of interpolation, although some field work was undertaken to complete information for the latest period.[7]

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[6] Except for the late medieval core areas in Mansfield-Ashfield, the pre-1880 period in both areas primarily involves development from about 1830 to 1880. Thus, the periods used decline in length fairly regularly from about fifty years, to forty, thirty, twenty, and twelve.

[7] Sources used were as follows:

London: 1839--Sketch of the position of London by William Syrs.
1845--Sketch of part of the London Township (author unknown).
1855--Map of City of London, Canada West, by S. Peters.
1856--Plan of the gravelled and other roads within seven miles of the City of London, Ontario.
1877--Map of the City of London and Suburbs, by J. Rogers. Scale 1:7920.
1886--Plan of the London Water Works, by T. H. Tracy, 1:2400.
(Copies of above plans in the University of Western Ontario Map Library.)
1886--Insurance Atlas of London, Ontario, by Chas. E. Goad, Montreal. Scales 1:600 and 1:1200.
1920-25--Geodetic survey of London, Department of the Interior, Canada, Published 1927. Scale 1:1000.
1950--Air photo mosaic of Greater London, published April, 1951. Scale 1:9600.
1960--Air photo mosaic.
1963--Air photo mosaic, Hunting Survey Corporation. Scale 1:9600.
1965--Topographic map, Corporation of the City of London, Lockwood Survey Corporation. Scale 1:2400.
1973--Air photo mosaic, Lockwood Survey Corporation. Scale 1:25,000.

(cont'd)

Figures 20 and 21 summarize the street-plan development of the two cities, according to these historical periods, and it is perhaps appropriate at this point to describe verbally the salient features of these evolving plans.

London

The basic concession grids of London and Westminster townships, upon which the City of London has subsequently evolved, were surveyed in 1810 and 1820 respectively (Ontario Government, 1969, Plate 99). The original city plan was laid out in 1826, and consisted of a uniform grid of about one square kilometre. This grid was extended to encompass a much larger area in 1840, with much of the added layout consisting of somewhat larger blocks. The 1840 plan is evident in Figure 20, bounded by the North and South Thames rivers (clearly indicated by sharp breaks in the street-plot), and by Adelaide and Huron Streets. By 1880, speculative development had already expanded beyond the city's grid, with considerable development in East London, but also some south and

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Mansfield-Ashfield:

1771--Map of Nottinghamshire, by John Chapman, printed 1785. Scale 1:63,360.
1836-40--O.S. 1:63,360 1st Edition, Shts. 82 (1840) and [illegible] (1836).
1876-84--O.S. County Series 1:2500 and 1:10,560, 1st Edition.
1897-98--O.S. County Series 1:2500 and 1:10,560, 2nd Edition.
1916-20--O.S. Popular Edition 1:63,360, 3rd Revision, Shts. 46 (1920) and 54 (1916-18).
1950--O.S. 1:10,560.
1958--O.S. 1:63,360, Sht. 112.
1966--O.S. 1:63,360, Sht. 112.
1960-73--O.S. National Grid Series, 1:2500, 1:10,560, and 1:10,000.
1972--Burrow's Reference Map of Sutton-in-Ashfield, 4th Edition, 1:18,000; Urban District of Mansfield Woodhouse, Street Map, approx. 1:7450; Borough of Mansfield, Engineer's Street Plan, 1:10,560.

west of the river forks. Layouts in these areas are often of higher road density than in the city proper. Whilst not always comprising completely connected grids, they nevertheless remain strictly rectilinear in character.

The suburban areas were incorporated by stages during the years 1885 to 1912, and almost all development until 1920 took place within the expanded city limits. A certain regularization of the evolving street-plan occurred between 1880 and 1920, with completion of layouts begun earlier, often to form grid patterns. The only evidence of curvilinear design is Windsor Crescent (south of the river off Wellington Road), begun toward the close of the period.

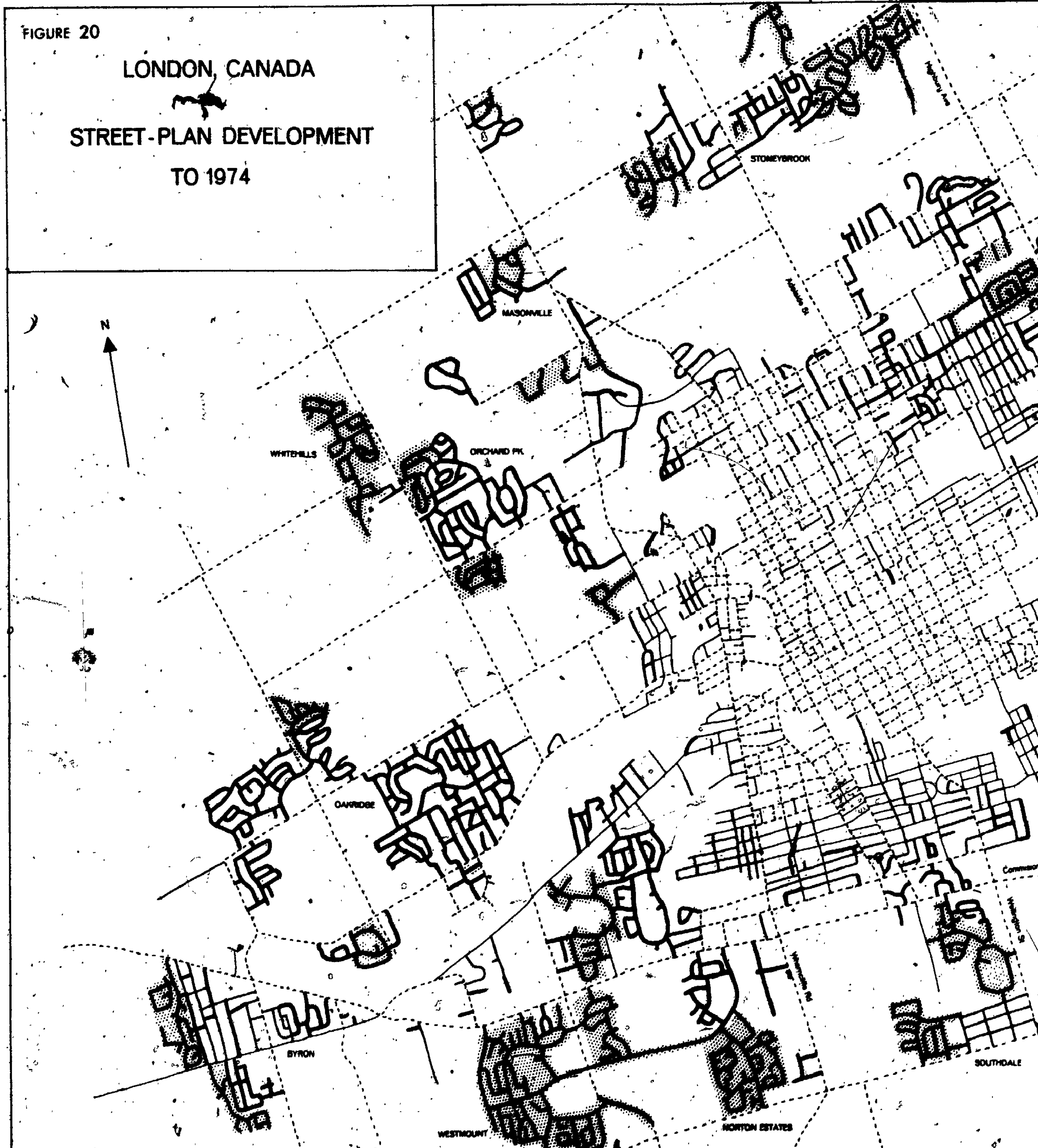
Rectilinear street patterns continued to be developed during the inter-war period up to 1950, even in new suburban subdivisions such as Southdale and Stoneybrook (Figure 20). Although relatively high density layouts were the rule in the city proper, very low densities were utilized in the suburban outliers. Again, the only attempts at curvilinear design were some small crescent layouts in south London.

The 1950-1962 period evidently marks a big break; although some of the earlier rectilinear layouts (e.g., Argyle Park in the east) are completed or extended in this period, most peripheral development is of curvilinear type. The styles or designs vary, however, with some subdivisions such as Oakridge Acres seeming transitional--road sections curve abruptly rather than gently, and most sections are in fact straight. The major difference lies in the connectivity rather than in curvature, since the majority of intersections are now T-junctions as opposed to four-way. The most advanced layout in this period is

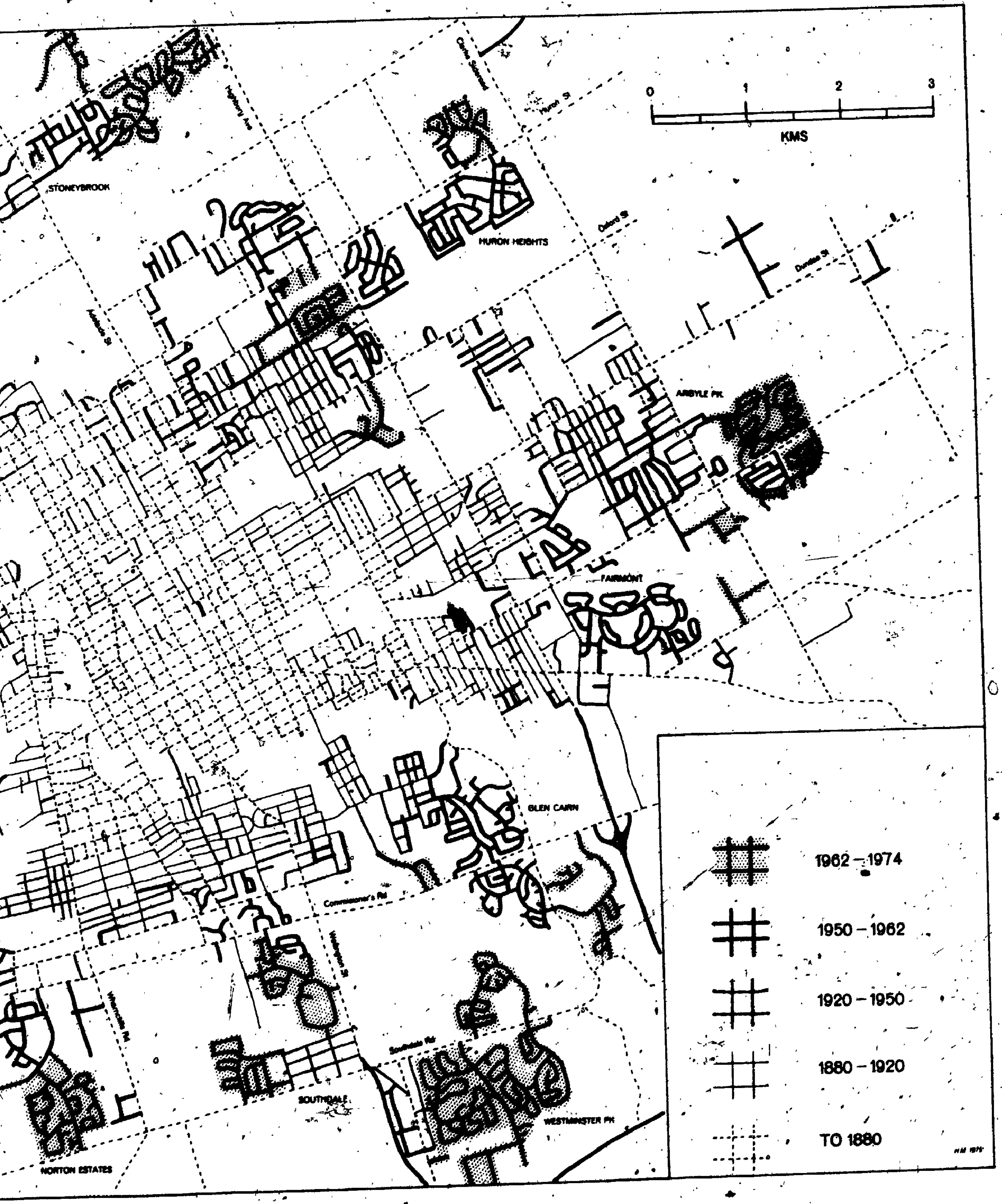
FIGURE 20

LONDON, CANADA

STREET-PLAN DEVELOPMENT TO 1974



[redacted]


0 1 2 3
KMS
STONEYBROOK
HURON HEIGHTS
Huron St
Oxford St
Dundas St
ARGYLE PK
FAIRMONT
GLEN CAIRN
Commissioner's Rd
Wellington St
Southdale Rd
SOUTHDALE
WESTMINSTER PK
NORTON ESTATES
1962 – 1974
1950 – 1962
1920 – 1950
1880 – 1920
TO 1880

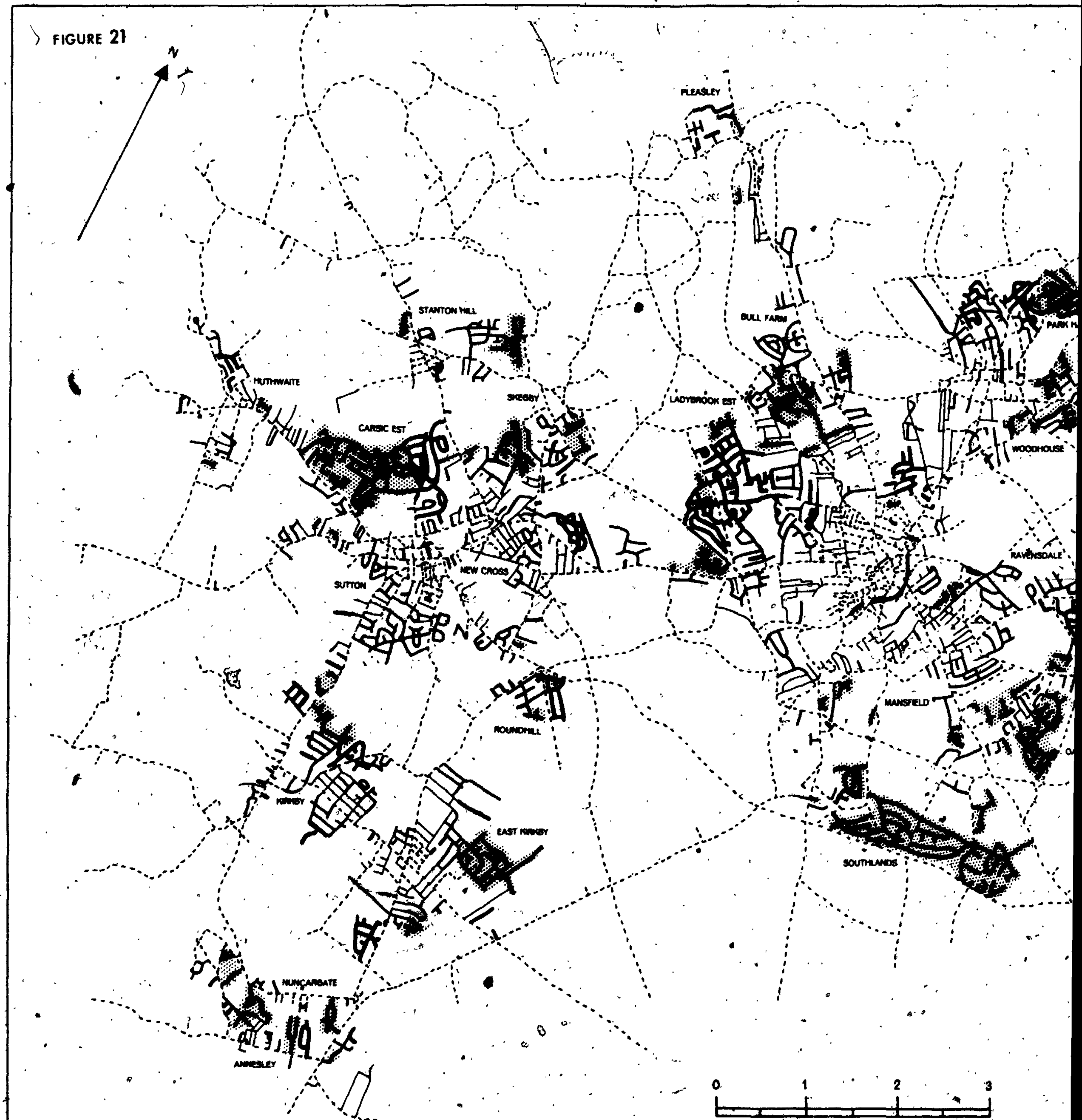
probably Fairmont, in the southeast, with gently curving distributor roads and loop access streets. Culs-de-sac are utilized in nearly all layouts, but to no great extent except in Glen Cairn.

In the final period, 1962 to 1974, there are no major rectilinear plans whatsoever. The majority of subdivision plans employ curvilinear distributor roads from which either loops or culs-de-sac run off. Very clear examples of loop design appear in the south at Westminster Park, and in the north at New Meadows, the eastward extension of Stoneybrook (Figure 20). Where loops are not used, culs-de-sac are heavily employed, as in Norton Estates and the extensions to Byron; both access strategies have advantages in terms of safety, quiet, and cost. Although it is difficult to judge by eye, it would appear from Figure 20 that net road densities have at least not fallen below those typical of the 1950's.

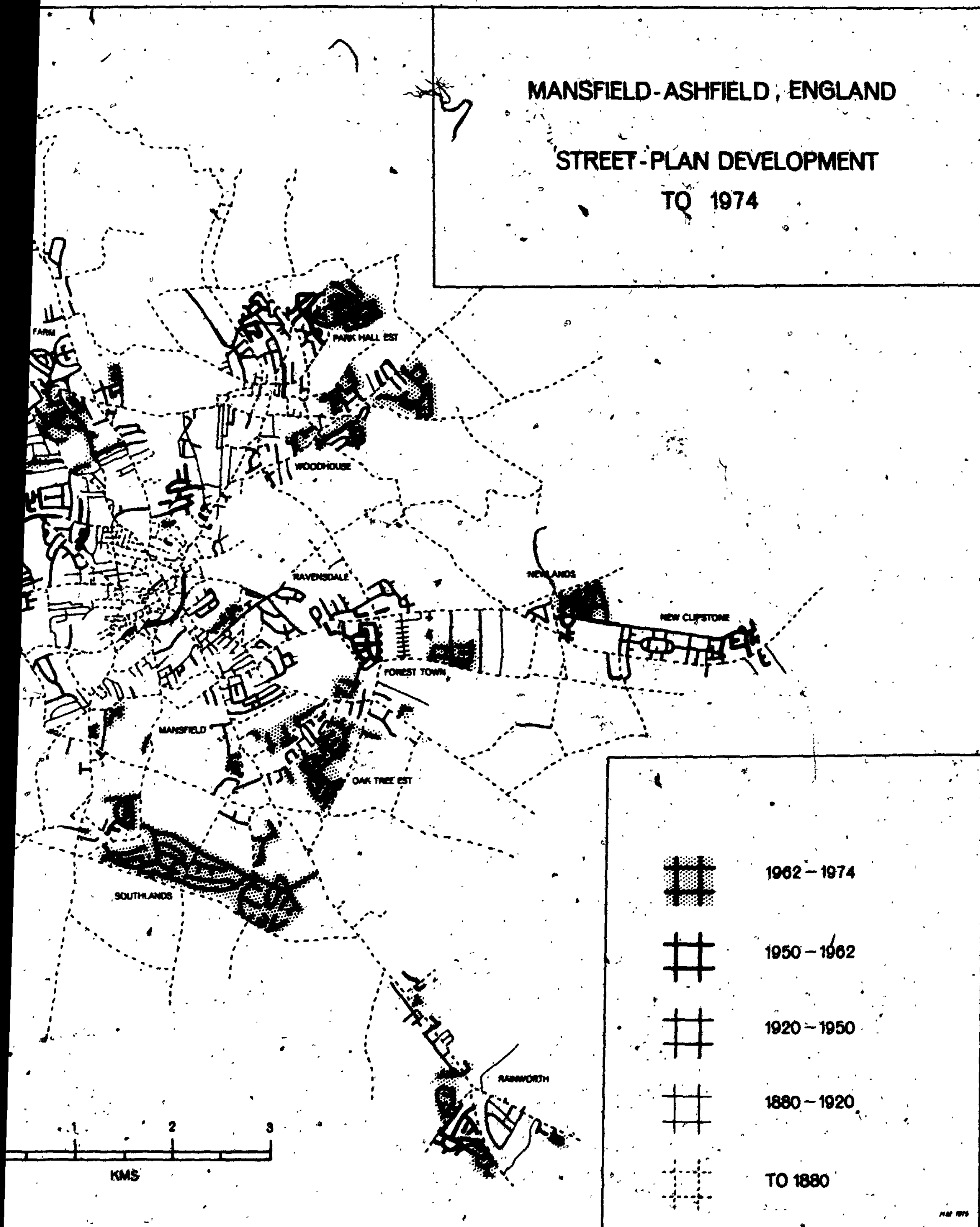
Mansfield-Ashfield

The most striking contrasts between Figures 20 and 21 lie in the higher road densities in the English area, and in the lack of any structuring macro-grid comparable to the concession roads in London. Instead, the pre-1880 roads were for the most part permanently established during the eighteenth century enclosures, and tend to reflect meandering desire-lines. No housing layouts of any size were developed prior to 1850, but after that date a few planned layouts (signalling the beginnings of industrial development) may be detected at East Kirkby, New Cross, and immediately west and south of Mansfield's core. Not shown in Figure 21 are numerous courts and alleyways in central

FIGURE 21



N
PLEASLEY
STANTON HILL
BULL FARM
HUTHWAITE
SKEGBY
LADYBROOK EST
CARSIC EST
WOODHOUSE
RAVENSDALE
NEW CROSS
SUTTON
MANSFIELD
ROUNDHILL
KIRKBY
EAST KIRKBY
SOUTHLANDS
NUNCARGATE
ANNESLEY
0
1
2
3
KMS


MANSFIELD-ASHFIELD, ENGLAND
STREET-PLAN DEVELOPMENT
TO 1974
FARM
PARK HALL EST
WOODHOUSE
RAVENSDALE
NEWLANDS
NEW CLIPSTONE
FOREST TOWN
MANSFIELD
OAK TREE EST
SOUTHLANDS
RAINWORTH
1
2
3
KMS
1962 – 1974
1950 – 1962
1920 – 1950
1880 – 1920
TO 1880

Mansfield and Sutton, many of which became lined with dwellings but which hardly constituted streets.

With the development of coal mining and hosiery industries in the area at the turn of the century, there were considerable extensions to the street-plan during the period 1880-1920. It is difficult to characterize layout design during this period, since each development is small in scale, often only a few streets. The road density is certainly reduced compared with very early developments, since this was the era of by-law housing. In most cases, densities were still the maximum allowed, but in the model colliery villages of Kirkby, East Kirkby and Rainworth, considerably lower road densities were employed. Throughout the area, layouts were generally rectilinear, with parallel streets (e.g., Forest Town, Woodhouse) and attempts at grids (e.g., Kirkby).

A major transition is apparent after the First World War, not only in the increased scale of developments but in the lower density of streets within developments. This is largely due to the introduction of municipal housing as a major market sector, with estates begun in Mansfield at Ladybrook, Bull Farm, and Ravensdale, in Woodhouse at Park Hall, and in Sutton south of the core area. These developments are generally curvilinear and employ culs-de-sac and some loops (features seldom utilized in London until the 1960's). Further development of mining communities takes place at New Clipstone, Newlands, Forest Town, Kirkby and Rainworth; these layouts tend to be more formal, with Clipstone noticeably rectilinear. Private single-family developments are generally not extensive during the inter-war period, and their most characteristic feature is low road density.

After the Second World War further large-scale municipal housing estates developed at Carsic Lane (Sutton), Ladybrook (Mansfield), and Park Hall (Woodhouse). Street densities in these areas are generally higher than in their pre-war equivalents, but designs are little different. Major private development occurs after 1962 at Southlands, Oak Tree Lane, Northeast Woodhouse, Forest Town and Skegby, again largely curvilinear layouts with some culs-de-sac. Southlands is very comparable to contemporary Canadian subdivisions in terms of road density. Very recent municipal developments, employing traffic separation through the Radburn principle, are discernible by their use of culs-de-sac penetrating to the layout interiors from peripheral distributors (e.g., the western extension of Carsic Estate, and Bellamy Road estate east of Southlands).

From this visual survey one might tentatively conclude that, whereas change through time in London is largely apparent in aspects of design, in Mansfield-Ashfield it is most clearly indicated by a change in density levels. In the English city, there is perhaps a greater range of design types during any one period, particularly considering the smaller amounts of development in most periods. The following two sections of this chapter investigate these trends by an analysis of indicators for $(500m)^2$ quadrats.

3. Spatial and Temporal Distributions of Layout Types

It is possible both to compare the two cities as composite entities, and to review their street-plans according to the nature of development in a series of time-periods. Several questions may be posed in comparing the English and Canadian patterns. With regard to the composite street-plans, how diverse are the layouts in each city, and to what extent are street-plans regionalized on each plan indicator? What is the scale of uniform regions within each city? (Does London, developed at a lower density, therefore show greater similarity of plan design in any given area?) Patterns of development through time may be reviewed in terms of other questions; for example, is there an increasing or decreasing range of net density, or curvature, through time?

Some answers to these questions may be gained through mapping and graphing the quadrat data summarized earlier in Chapters III and IV.[8] For each of the four indicators utilized in the typology (net road density, angular deviation, connectivity, and curvature), quadrats are mapped according to the three categories defined by the typology limits (the categories for net road density, for example, are simply high, intermediate, and low). The quadrats are also plotted with respect to the decade during which the majority of their street sections were laid out.[9] The dates of development may be considered as

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[8]The variable-by-variable method outlined here is not the only method of investigating regional patterns of street layouts within the two cities. The author also employed an hierarchical grouping procedure (using the net density and four design variables) to group quadrats in each city, and mapped the five groups obtained for each. This approach, however, poses difficulties in identifying the common characteristics of each group (that is, in "naming" them), and is a good deal less objective than the simple descriptive approach.

[9]In some quadrats, of course, it is spurious to fix such a precise time interval on the date of development, as the street pattern in their 25-hectare areas may have grown incrementally through several decades. This is the case in very few of the sample quadrats, but nevertheless the reader is cautioned to view the graphs in Figures 22 to 25 as indicative only.

an independent variable, and scores for the plan indicator as a dependent variable.

Net Road Density

Road densities are generally higher in the English city, and Figure 22 shows this fact. It also shows that the areas of higher and lower density are grouped into a definite centre-periphery pattern in London, but not in Mansfield-Ashfield. The pattern of high versus intermediate density in the latter appears almost random.

Turning to the distributions by time of development, also shown in Figure 22, we are able to discern some temporal trends. In London, the range of net density levels has never been very large, and does not seem to be increasing. In both cities, net densities appear to have risen in the last few decades, from low levels in the 1930's and 1940's. Densities did not decrease during the late nineteenth century in London (rather, the reverse), in contrast to the apparent decline in Mansfield-Ashfield.

Angular Deviation

Regular street-plans are more evident in London than in Mansfield-Ashfield (Figure 23), and again there appears to be more regionalization on this indicator in the Canadian city. Irregular layouts occur largely west of the centre, either owing to changes in grid alignment or occurring in new subdivisions. In Manfield-Ashfield there are some regular layouts, but they do not tend to cluster as in London.

The historical trends differ markedly. London's street layouts have always been planned to a greater extent than in the English city,

FIG 22 EXAMPLE CITIES: SPATIAL AND TEMPORAL DISTRIBUTIONS OF NET ROAD DENSITY

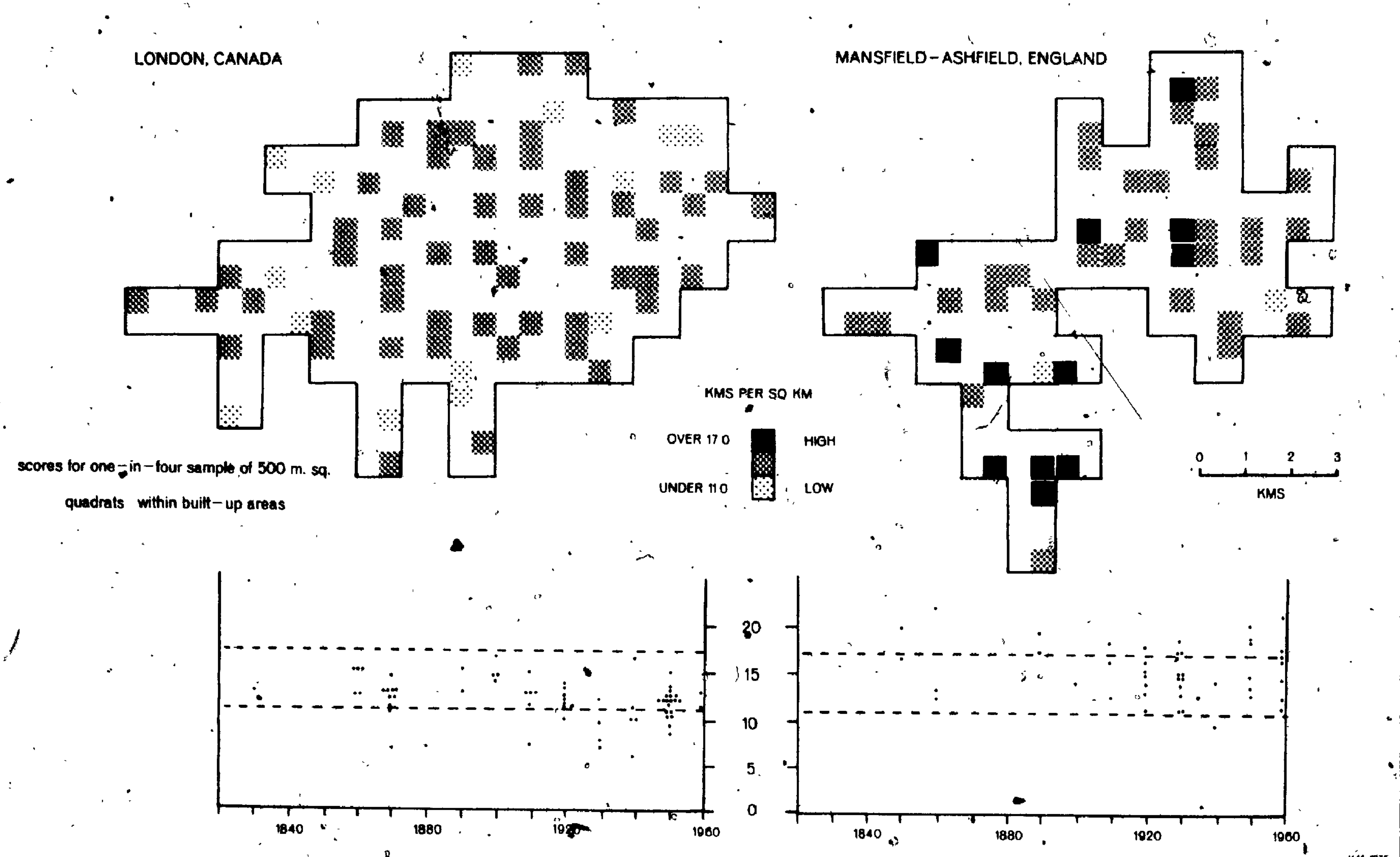
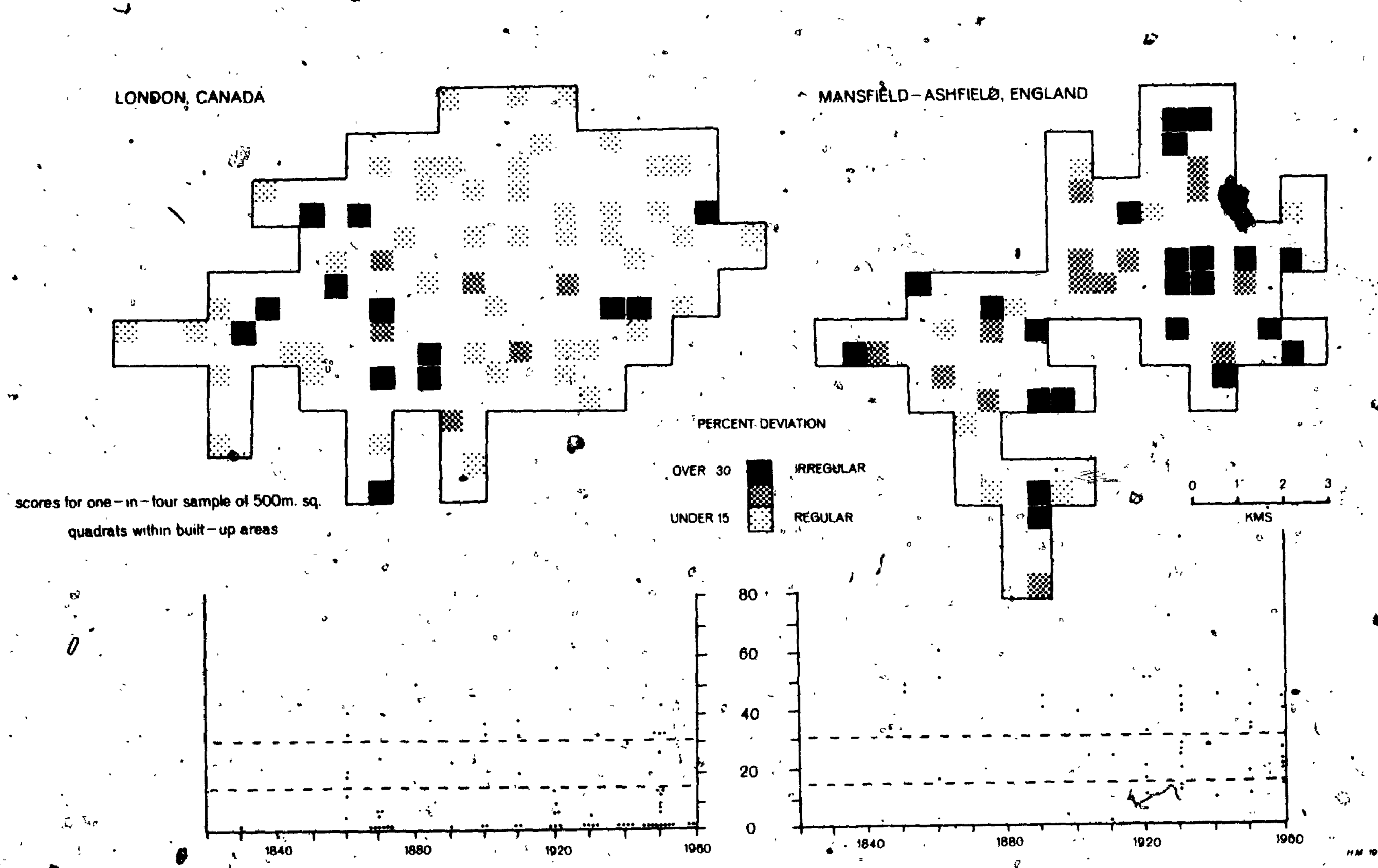


FIG 23 EXAMPLE CITIES: SPATIAL AND TEMPORAL DISTRIBUTIONS OF ANGULAR DEVIATION



with the least regular layouts being developed in the periods 1880-1910 and around 1950. In Mansfield-Ashfield, angular deviation has consistently been higher, but has declined steadily through time. The range on this plan indicator has been quite similar in both cities, but the distributions of scores in particular decades have generally been much more skewed in London.

Road Connectivity

It is not surprising that high junction valencies, indicating grid-pattern layouts, should be far more evident in London than in Mansfield-Ashfield (see Figure 24). In the Canadian city, the decrease in valencies from the centre outwards reflects the historical decline very well; the temporal distribution shows a steady decline through time as grid layouts are abandoned in favour of three-way junctions, and more recently culs-de-sac. A similar decline is less evident for Mansfield-Ashfield, and the average valency remains quite constant at about 2.7. No quadrat in the English area can be characterized as displaying a grid pattern, and the ranges in most decades are less than in London.

Road Curvature

Both cities contain a number of curvilinear and rectilinear layouts, but London in 1961 has relatively fewer curvilinear patterns, more noticeably distributed around the periphery (Figure 25). This suggests that they are a recent phenomenon, a fact borne out in the graph of development dates plotted against percent curvature; the great majority of curvilinear street patterns in London are developed

FIG 24 EXAMPLE CITIES: SPATIAL AND TEMPORAL DISTRIBUTIONS OF ROAD CONNECTIVITY

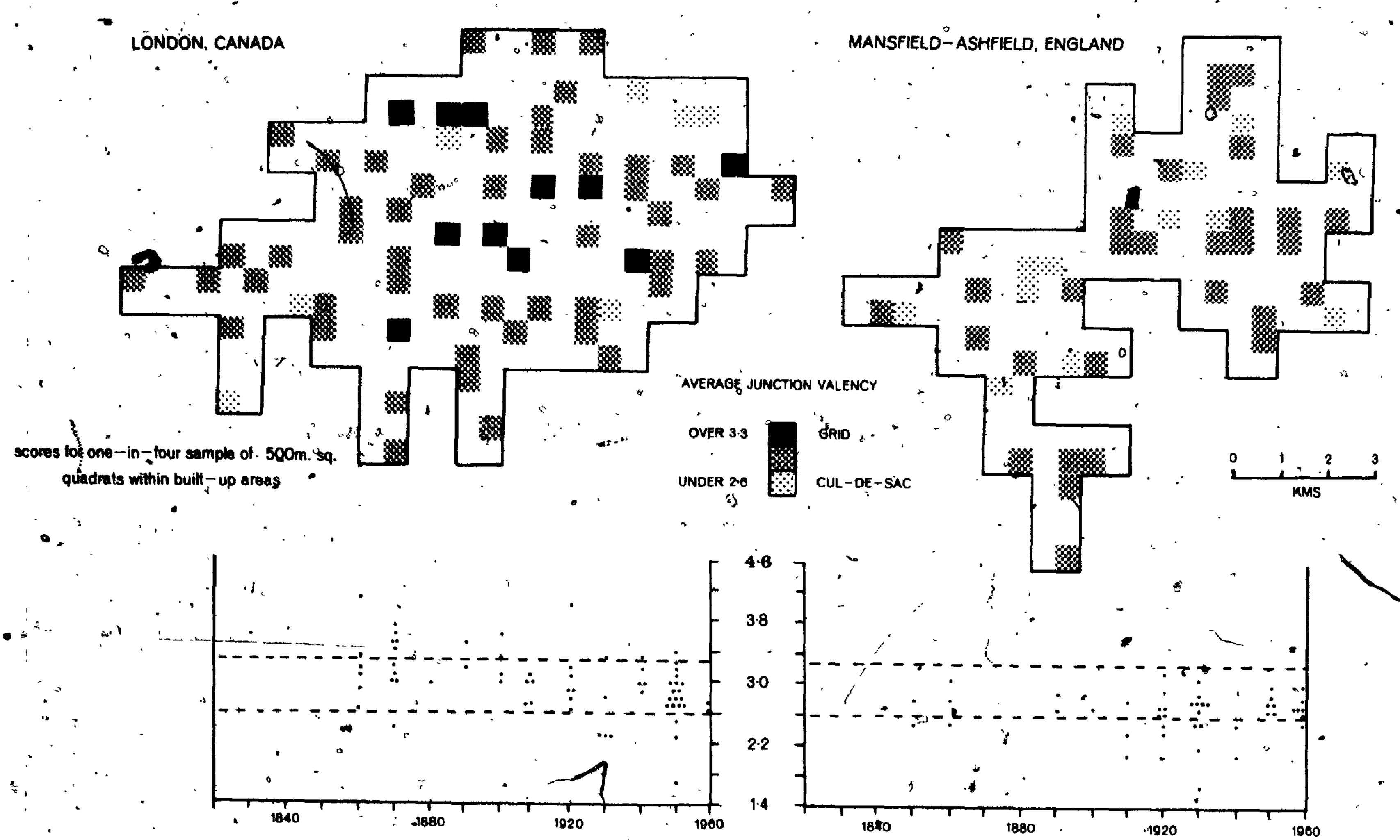
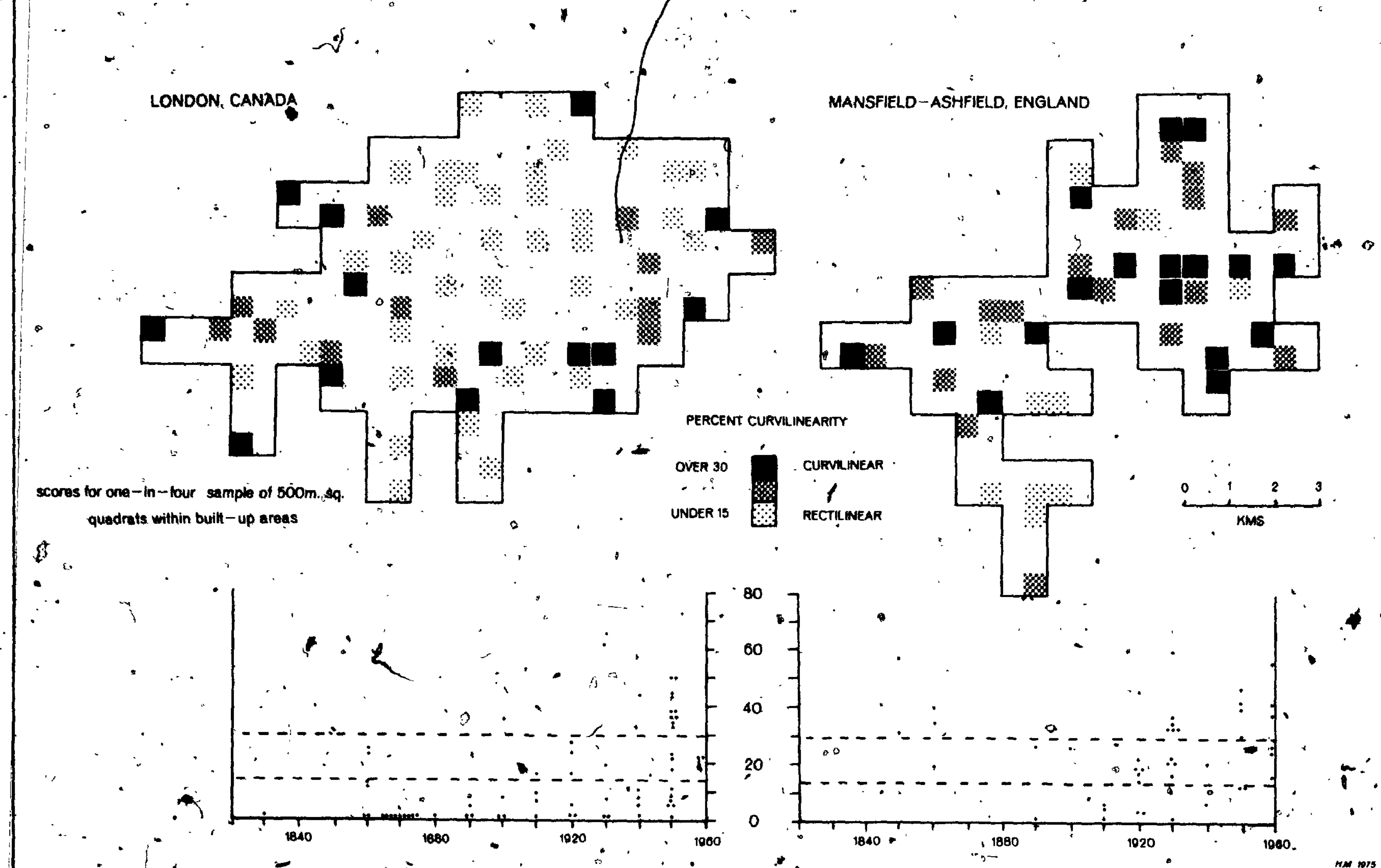


FIG 25 EXAMPLE CITIES: SPATIAL AND TEMPORAL DISTRIBUTIONS OF ROAD CURVATURE



after the Second World War. Note that in Mansfield-Ashfield curvilinear layouts are the general rule, but that during the early part of this century several very rectilinear areas were built (mainly in East Kirkby). In both cities, there appears to be a recent increase in the use of curvilinear plan forms.

The following section will survey recent street layouts and set the entire historical trends in the context of form-convergence and the homogenization hypothesis. But before going on, it is germane at this point to test the validity of the earlier surrogate for time of development, namely distance from the city centre.

The spatial extent of development in these cities has generally increased through time at a more rapid rate than the areas of concentric rings defined by successive radii at unit intervals (in similar fashion to the example in Chapter IV, Section 1). Thus, it is likely that a logarithmic model, comparing age of street-plan against the logarithm of distance, will yield higher correlations than a simple arithmetic model.[10]

This is in fact the case for the two example cities. For each quadrat, the independent variable was taken as straight-line distance from the city centre (or nearest of two centres in Mansfield-Ashfield) in kilometres, and the dependent variable as 1970 age of development in decades. For the sixty-seven London quadrats, the highest simple correlation (-0.73) was given by the equation $Y = 20.8 - 4.43 \log X$.

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[10]Simple correlations for the arithmetic model were -0.71 for London and -0.36 for Mansfield-Ashfield.

This would seem to validate the earlier use of the distance surrogate in Chapter IV, as one might expect similar correlations in all uni- and bi-nodal cities. The correlation in Mansfield-Ashfield, however, was much lower (-0.49 for the equation Y = 11.2 - 2.36 log X). The poorer fit is readily explained, since there are in fact more urban nodes in the area than the two used to compute distances--besides Mansfield and Sutton-on-Ashfield, there are two other towns and a number of mining villages. If all these nodes were used in computing distances, one would expect a correlation very ~~similar to that~~ obtained in London. Nevertheless, the validity of the surrogate as used in Chapter IV is questionable both for Mansfield-Ashfield and for the other multi-nodal city, Burnley-Nelson.

4. Recent and Currently-Planned Layouts

This section completes the construction of historical trends based on the measurement of objective street-plan characteristics. The sample quadrats examined so far refer to the built-up areas as delimited for 1961 and 1950, the latest survey dates for 1:25,000 topographic maps. To round out the analysis, therefore, areas of post-1962 development were identified in each city and sampled by $(500\text{m})^2$ quadrats; in the case of Mansfield-Ashfield, ten such quadrats almost exhaustively covered all such development, whilst in London a representative sample only was taken. Since these quadrats were not chosen on the same basis as in the previous comparative work, their gross road density measures are not truly comparable with those for other time-periods; all other measures, however, are.

The layout designs in this recent period have already been discussed in general terms with reference to Figures 20 and 21. It remains to set their design and density characteristics into the context of the entire historical trend in each city. For each historical period, mean scores on each indicator are computed (and listed in Appendix C). These are then plotted against time of development and shown as frequency polygons in Figures 26 and 27.

The graphs provide answers to the question "for which design and density indicators is increasing similarity most evident?" In every case, the means move in this final period in the same direction in both cities. Thus, net road densities increase in both, reaching their highest levels ever in London (Figure 26B), and road junction densities attain their highest historical levels in both cities (27A). Similarly, both cities show trends toward lower connectivity (27B), lower angular deviation (27C), and higher road curvature (27D).

An increase in similarity, however, is not apparent for all these indicators--there is in fact some divergence with respect to junction frequency and connectivity. Does this greater dissimilarity suggest the absence of an innovation-diffusion process operating on street-plan design? Hardly, for the sharp decreases in connectivity and rapid increases in junction frequency mark the almost simultaneous adoption in both areas of cul-de-sac layouts based on the Radburn-clustering or superblock principle, particularly for single-family detached housing developments. A specific design innovation has come "on-line" at almost the same time, in contrast to adoption lags for earlier design fashions such as curvilinear layouts. And although

FIG 26 EXAMPLE CITIES: TEMPORAL TRENDS IN STREET AND DWELLING-UNIT DENSITIES

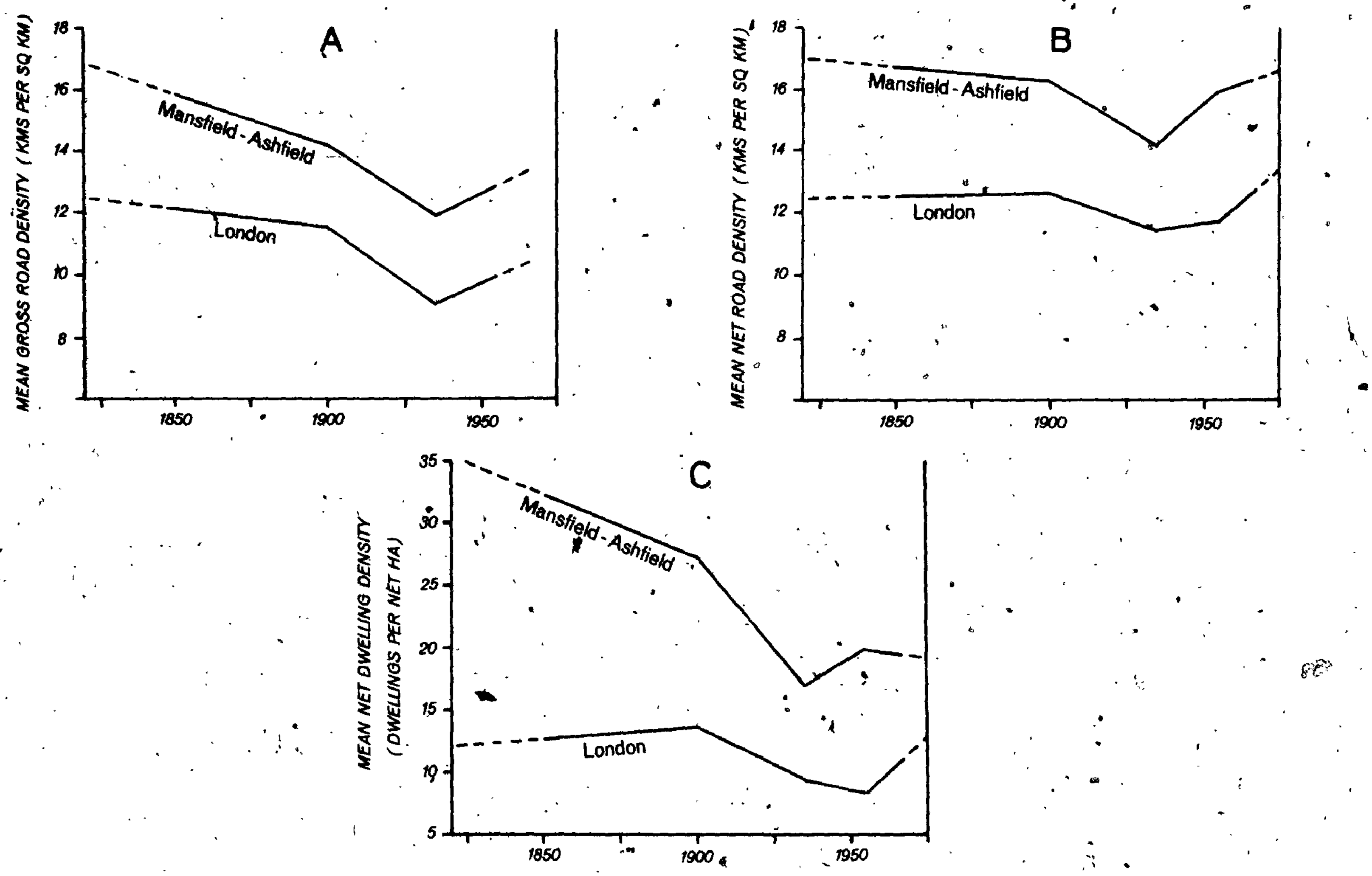
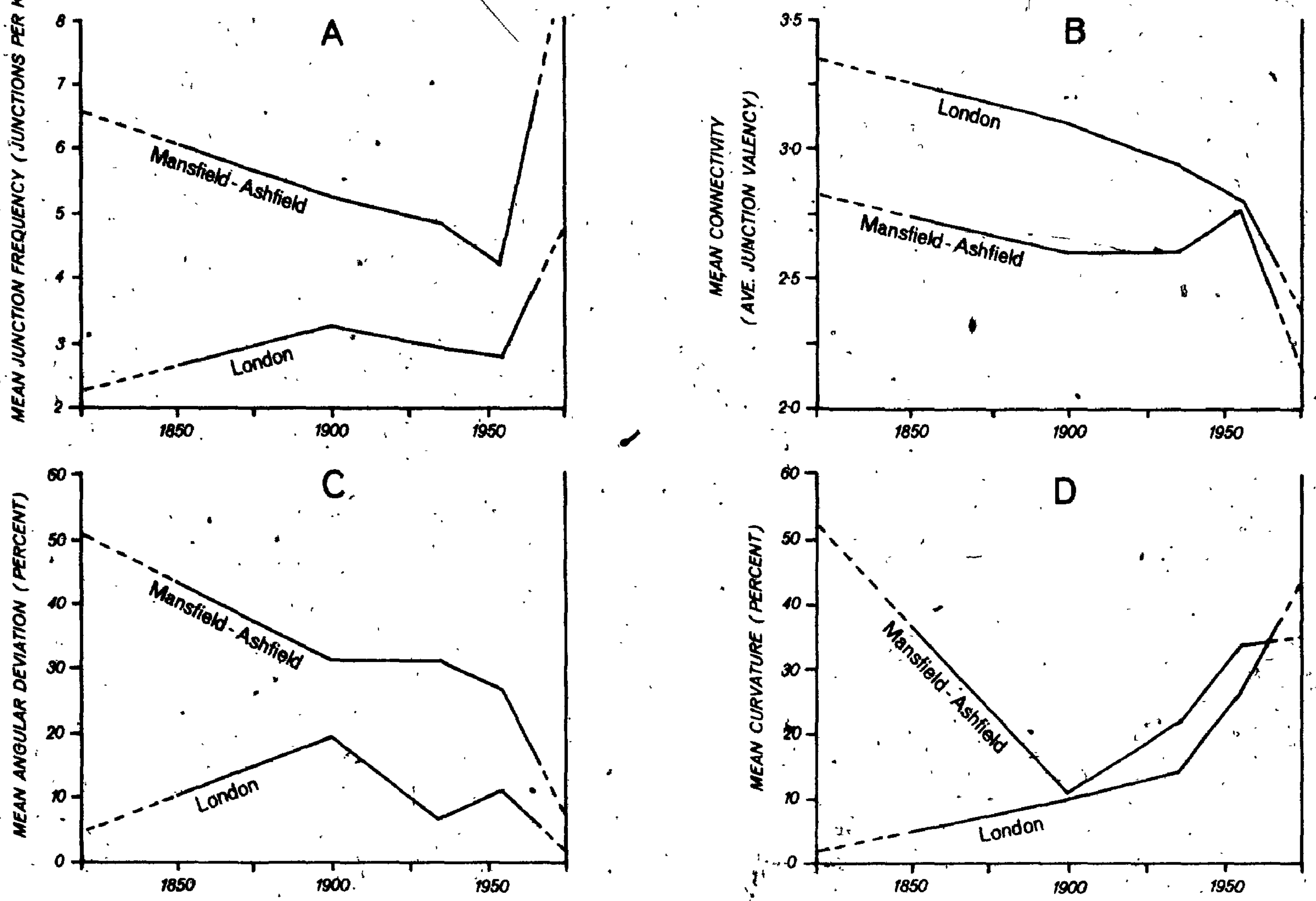


FIG 27 EXAMPLE CITIES: TEMPORAL TRENDS IN STREET LAYOUT DESIGN



there may have been some slight quantitative divergence owing to initially differing adoption rates, there is nevertheless qualitative convergence.[11]

Aside from the trends apparent for particular plan measures, do P-indices show recent plan forms as a whole as being more or less similar than those in previous periods? For the pre-1880 period, the overall disparity between layouts in the two cities is 39.9 percent of the maximum possible.[12] The disparity falls rapidly to 20.7 percent (1880-1920), and fluctuates around this level in the more recent periods, going from 22.8 (1920-1950) to 17.6 (1950-1962) and 18.4 (1962-1974).[13] The suggestion is that post-1880 developments have been quite similar in all time-periods, but that no real reduction in disparities has occurred since that date. This accords with our expectations (given in Chapter I, Section 2), regarding the presence of intrinsic constraints peculiar to each national area, which set limits to the extent and rate of form-convergence, particularly, it seems, with regard to densities. Incremental developments have become more similar in form, and continue to converge on some aspects, but taking all indicators into account, the homogenization trend has apparently stalled. It is important to note, however, that the composite

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[11] See the discussion of Horvath's ideas in Chapter I, Section 2.

[12] See the method of index construction given in Chapter IV, Section 3.

[13] Note that P-indices for the two cities computed from data by concentric zones show a very similar trend, being, in sequence, 36.3, 22.5, 20.3 and 21.2 percent--a further indication that the distance surrogate gives a reasonable picture of the historical trend.

street-plans of the two cities have converged at a steadier rate,[14] and may be expected to continue convergence in the near future.

What densities and design features are incorporated into street layouts presently under construction or planned for the near future? May we expect further homogenization to occur, or will designers in the two countries continue to apply slightly different design criteria? Although these questions are largely rhetorical, the design literature and some currently-planned developments in the example cities provide a basis for speculation. In discussing them, comments will be confined to aspects of design, leaving aside the matter of density until the following chapter.

Mansfield-Ashfield is growing more slowly than London, and the number of housing completions per year is likely to average only about 800-1000 over the next decade.[15] Based on current proposals, over one-half of these units will be developed as municipal housing. The capital building programme for the Mansfield District is presently planned only to 1977, with major development to take place primarily at the Sandy Lane, Oak Tree Lane, and Bellamy Road estates. No final site plan for Oak Tree Lane has been approved, but the proposed road network is a circular internal distributor with two external access points, and minor access roads to neighbourhood housing groups.

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[14] P-indices for evolving composites are: 39.9 (1880), 30.3 (1920), 25.5 (1950), 21.2 (1962) and 23.8 (1974).

[15] Information from "Appendix A, Interim Report of the Housing Working Party", Mansfield-Alfreton Growth Zone Committee, October, 1973, and from "Report with Regard to the Capital Building Programme", Housing Sub-Committee No. 2, Mansfield District Council, December, 1973.

Suggestions for interior common land and separation of pedestrian and vehicular traffic point to the wholesale employment of the clustering principle.[16]

The Sandy Lane development is primarily a redevelopment project, and on a much smaller site. Streets are entirely short access roads leading to eleven interior parking courts. All intersections are planned to be at right angles, and most road sections are slightly curved.[17] Exactly similar design principles are evident in the site plan for the final stage of the Old Newark Road housing estate. Private developers in the area are being encouraged also to adopt traffic separation through the use of peripheral distributors and short internal-access culs-de-sac; such features will be less likely, however, in high quality, low density developments, where large private lots (as opposed to "minimal gardens") will continue to necessitate conventional street layouts.

London's rate of population increase has slowed in recent years to around three percent per annum (Goracz et al., 1971, 135), and annual housing completions are likely to average no more than about 2,500 units during the next decade.[18] Based on the current market mix,

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[16]From memo on "Land at Oak Tree Lane, Mansfield, and Proposed Development," Mansfield Borough Engineer and Surveyor's Office, September, 1973.

[17]Information from Site Plan, Sandy Lane/Gladstone Street Development, Mansfield Borough Engineer and Surveyor's Office, February, 1973.

[18]At the time of writing, latest available statistics are for August, 1974 (Canadian Housing Statistics, Central Mortgage and Housing Corporation). From January to the end of August, 2,211 units were

at least 1,800 per year will be single-family units, either attached or detached.

Site planning criteria in London, as in the rest of Ontario, are much more specific to the local planning authority than is the case in England, and in this difference lies the possibility for contrasts between the two example cities in future layout schemes. In Ontario, the City Engineering Department and the City Planning Board staff have in practice a great deal of control over the total layout, but it could fairly be said that an emphasis on creative civic design is not common, and desirable draft plans may be compromised by inflexible local standards of a quantitative nature.[19]

In London, draft subdivision plans for two of the largest proposed developments (Whitehills extension and White Oaks) show similarities in approach, evidently owing to the influence of planning and engineering departments. These areas, to be developed over the next five years, are characterized by "textbook" loop systems; each loop penetrates the superblock interior about 300 to 400 metres, and junctions along distributors occur at equal intervals of about eighty metres. There are very few four-way junctions, yet although average junction valency is as low as 2.3 culs-de-sac are employed only where they are obviously necessary to gain maximum lot yield from the site.

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started in London; 37.3 percent were single-detached, 33.1 percent single-attached (including row-housing), and 29.6 percent were multiple units.

[19]For a summary of the Ontario subdivision approval process, including a concise discussion on problems in layout design, see Ontario Economic Council (1973, 62-71).

Draft subdivision plans do not indicate vehicle access and parking within row-housing areas, since in London such access is not dedicated. One expects that future single-family attached housing will employ layouts and groupings similar to those in Mansfield-Ashfield but that any particular such development will tend to be smaller in scale, because of an emphasis on mixed housing and the absence of a large-scale public sector.

This brief survey of planned developments in the two example cities does not suggest further between-city convergence of street layouts in the near future. And there will probably be an increased diversity of layout types within each city, as cluster housing is introduced alongside continuing "conventional" developments. In both areas, however, designs reflect certain principles which are at present very firmly established in the design literature. House- and lot-grouping based on traffic separation is the primary focus of current innovations in layout design, with the access system being planned integrally with the plot and dwelling arrangements. As a result, almost all layouts utilize either loops or culs-de-sac and parking courts, with peripheral distributors.[20] Accepted cost, safety, and aesthetic principles touched on in Chapter II are still strongly urged in the most recent design manual available (Urban Land Institute,

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[20] Such street designs have been shown to be preferable both in cluster-housing and conventional "maximum-garden" schemes, as the cost comparisons by De Chiara and Koppelman (1969, 118), Kostka (1957, 80), Farnum Kerr Associates (1963) and the Ontario Community Planning Branch (1958) show.

1974). In terms of the street-plan measures used in the present study, uniform adoption of these principles would lead to:

(a) almost no angular deviation whatsoever; all junctions at right angles;

(b) road curvature similar to present levels, around thirty to forty percent;

(c) all junctions either three-way or cul-de-sac, giving connectivity measures as low as 2.0 to 2.2;

(d) either high or low junction frequencies, depending upon whether layouts employ culs-de-sac or loops, respectively.

5. Summary

This chapter has examined the changing nature of street-plan features through time in two cities representative of the typical Canadian and English urban development experience. Each street section existing in early 1974 was assigned an approximate date of construction, and the patterns of layouts in five time-periods then described, both verbally and statistically. Perhaps the major finding is simply the very great increase in similarity between the two cities during the period 1880-1920, and the essentially "parallel" trends in layout design and density which they have followed since. Computations of disparity indices per period bears this out, with the disparities between the two in successive periods reducing only slightly since 1920. Note, however, that only in the most recent period can layouts in both cities be described in the same category according to the street-plan typology; they are both "Regular cul-de-sac curvilinear".

Based on a review of some planned layouts, it is suggested that the composite urban forms will continue to increase in similarity, but that street layouts constructed during the next decade will not show greater similarity than those developed in the recent past. Stated in the context of the present analysis, the disparity or P-index for, say, 1974-1986, will quite probably be similar to the 18.4 percent recorded for 1962-1974.

CHAPTER VI

TEMPORAL TRENDS IN DWELLING DENSITIES AND COVERAGE RATIOS

1. Plots, Dwellings and Density

In analyzing temporal trends in the design and density of plan elements, we have so far examined only street patterns, as the most permanent and easily-identified indicators. But, the notion of morphological convergence, and the model of innovation effects introduced in Chapter I are equally applicable to the other major plan elements--plots and buildings. The three elements are, in fact, interrelated aspects of residential layout design.

Often the major determinant of street layout design, street density, dwelling-type, and lot or garden[1] size, is simply the overall gross density required for the site. Once this is decided, and once the amount of the site required for non-residential ancillary land uses is determined from the projected population, the rest must follow perforce. Alternatively, restricted area by-laws concerning maximum density (sometimes couched in terms of minimum lot size) will determine not only dwelling densities but also the street layout design and housing type.[2] Since in Canada lot depth has recently been fairly

[1]A dwelling-plot is generally termed a lot in North America, a garden in England.

[2]The Community Builders' Council (1960, 87) provides a table of

standard at 100 feet, one could further suggest that the most direct indicator of net density is simply lot width.

Owing to these relationships, one may usefully summarize aspects of plan density by computing dwelling-unit density. Such a density measure is considered as important according to several criteria. For example, to the developer, it relates to profit maximization, especially when land costs are relatively high. If there are many marginal buyers, the higher the land costs, the more attractive is high density (or high "lot yield").[3] The majority of consumers will purchase space if they can afford it; that is, lot size is positively related to income, and an increase in general prosperity will <u>ceteris paribus</u>, be accompanied by decreasing net densities. Site planners and city planners take a variety of attitudes towards optimum density levels, based on at least four criteria: urban efficiency (reaching thresholds of economic service for a range of utilities and facilities),[4] land consumption, the question of pathology, and aesthetics. To all actors in the market, density is often a more important consideration than the quality of design.

Residential densities may be defined either in net or gross (neighbourhood) terms. Basically, net density is computed either from

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lot sizes with their corresponding net dwelling-unit densities and recommended unit types.

[3]For those builders catering to the upper income portion of the market, an alternative adjustment to rising site costs is to increase the size and quality of the house on the lot, so maintaining land costs as a constant proportion of total costs. See Clawson and Hall (1973, 129).

[4]See Whyte, 1970, 377-382.

the land area in plots and dwellings alone (e.g., Lynch, 1971, 314), or including adjacent access streets. In this analysis, I will follow the Town and Country Planning Association (1964, 101) in taking the number of dwellings divided by the hectare area in dwellings, plots, incidental open space (e.g., parking, "totlots," pathways), and half the width of the adjacent roads.[5]

One other definition is in order here. The analysis in this chapter concerns itself only with single-family developments, partly because multiple-family areas would require separate methods of density measurement, but largely because there are few examples of apartment buildings even in London until the post-war period (and very few to date in Mansfield-Ashfield) so that their inclusion would mask density trends in the major market sector. What precisely are single-family dwellings? They may be defined narrowly to exclude attached and semi-detached units (e.g., Lynch, 1971, 297), or more broadly as all units with direct access to ground level and including a minimum private ground space.[6] Since the great majority of non-flatted units in

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[5]Up to a maximum of ten metres, to except major non-local roads. Land devoted to local shops, primary schools and neighbourhood open space is also excluded. Gross density is defined here by hectare area including these local uses, but excluding all other urban uses such as industrial, commercial, major open space, and secondary schools. Both net and gross densities may be expressed in terms of people (persons per ha.) or the accommodation which they occupy (number of habitable rooms or dwellings per ha.).

[6]This is in line with Canadian housing statistics, in which there are three major categories of single-detached, single-attached (semi-detached, duplex, and row-housing), and multiple. In U.S. statistics, row-housing units are officially considered as either single-family or multiple-family based on whether their connecting walls are exterior or interior grade (Zehner and Marans, 1973, 337).

England are either row (terrace) housing or semi-detached, the definition of single-family as all non-apartment units will be used here.

2. Trends in Single-Family Dwelling-Unit Densities

Large-scale plans and maps were used to compute approximate net dwelling-unit densities in the two example cities. All single-family units existing in early 1974 were included, so that the data do not take account of units constructed in early periods which have since been subject to clearance and renewal.[7] Units were counted as if they were all in their original state, so that subdivision of units subsequent to construction, and changes in use, are also not accounted for. This procedure was considered appropriate to an analysis of trends through time, as it gives a more accurate picture of densities at the time of development, while still presenting a summary of the city's physical plant as it currently exists.

Information was primarily taken from recent plans at 1:2,400 and 1:2,500 scales,[8] with field work to update to early 1974, and to enable enumeration of row-housing units, particularly in London. Some large-scale (e.g., 1:1,250) site plans were consulted to update

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[7] In both cities there has been little replacement of original units outside the very central areas, so that the net effect of this procedural condition is a slight under-estimation of the number of dwellings built prior to 1880, and perhaps also of the net density in that period.

[8] For London, the 1965 topographic map by Lockwood Survey Corporation (1:2,400) and the 1973 Pathfinder map (approx. 1:16,200). For Mansfield-Ashfield, O.S. 1:10,560 (SK 55SW, 56SW, 56SE, 55NW, to 1963) and 1:10,000 (SK 45 NE, 55NE, 46SE, 45NE, to 1973), supplemented by 1:2,500 sheets in the two central areas (SK 5361, 5461, 5360, 5460, 4958).

information for Mansfield-Ashfield. Based on these sources, small areas[9] of apparently uniform plot dimensions were identified, and the hectare area[10] and number of dwelling structures in each obtained. The period of development of these areas was estimated using Figures 20 and 21, and historical maps (listed in Chapter V, Footnote 7).

Figures 28 and 29 display the resulting spatial distributions of net density of the two cities, and may be compared with the maps of street development. One can immediately appreciate the much higher densities in Mansfield-Ashfield (Figure 29), with even areas of detached housing having densities up to twenty units per hectare.

Aside from areas of multiple-family units, and a few townhouse developments, London lacks areas with net densities over twenty-five per hectare. Very large portions of the city's residential area have densities of fifteen per ha. or less, and much peripheral development is at ten and below.[11] By comparison, in Mansfield-Ashfield, there are only two areas of any size with densities below sixteen per hectare

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[9] Five hundred and seventy-six small parcels in London, generally in the range of five to twenty-five hectares; 432 parcels in Mansfield-Ashfield, mostly in the range of two to fifteen hectares.

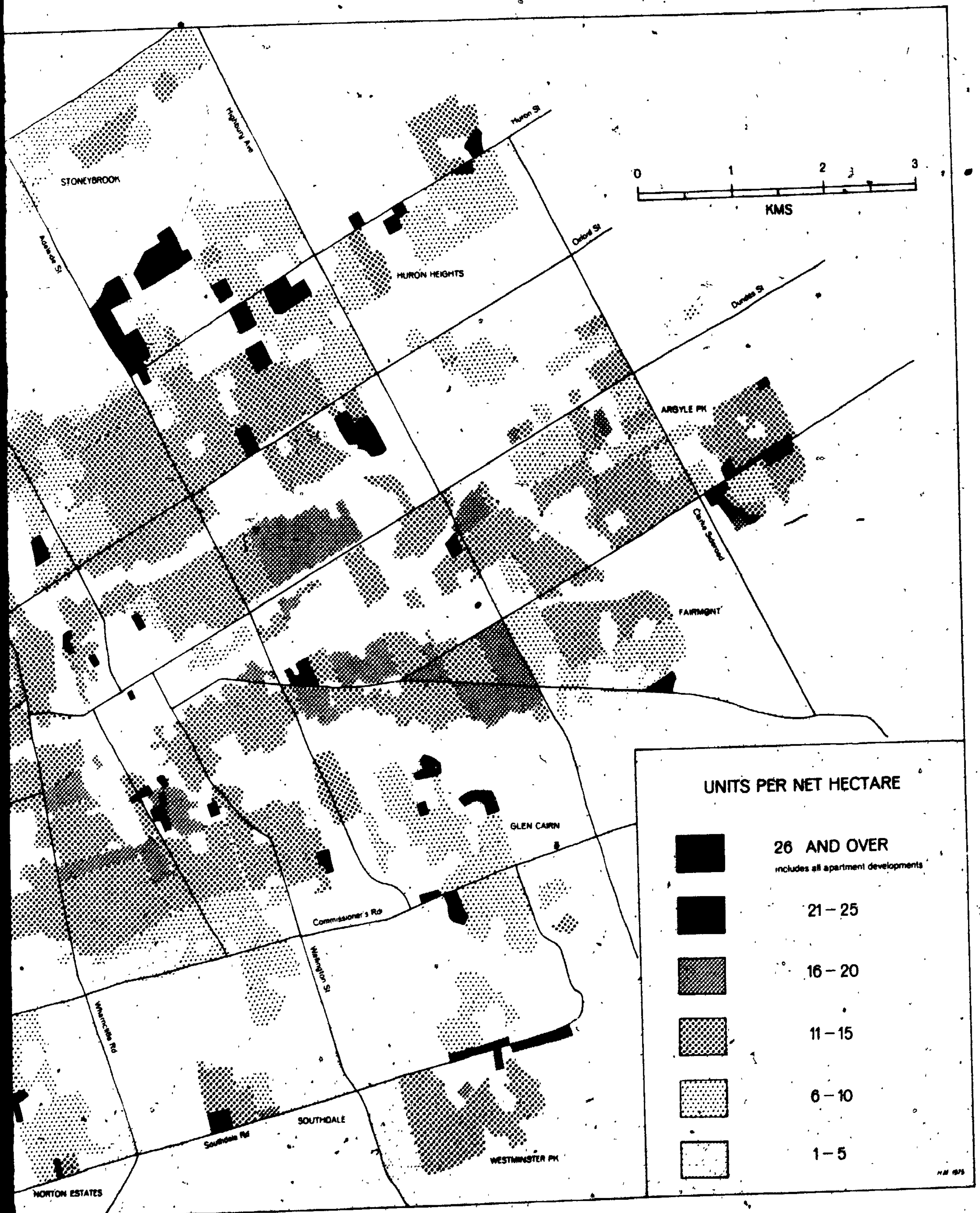
[10] Largely by superimposition of a quarter hectare grid, since planimeter measurement was found to be less satisfactory in terms of precision and time consumption.

[11] It is worth noting that a strong distance-decline gradient is absent in both cities. Although this may appear contradictory to a body of empirical evidence on gradients (for example, by Clark (1951), Tanner (1961), Newling (1969) and Berry and Horton (1970, 293)), one should bear in mind that such evidence seldom refers even to gross residential densities, but rather to gross densities on the basis of area in all land uses, including non-urban. There is, however, some evidence in Figures 28 and 29 of both concentric and sectoral density patterns. As will be noted shortly, densities are currently rising and will continue to rise, producing an outer "ridge" of more intense development.

FIGURE 28

LONDON, CANADA

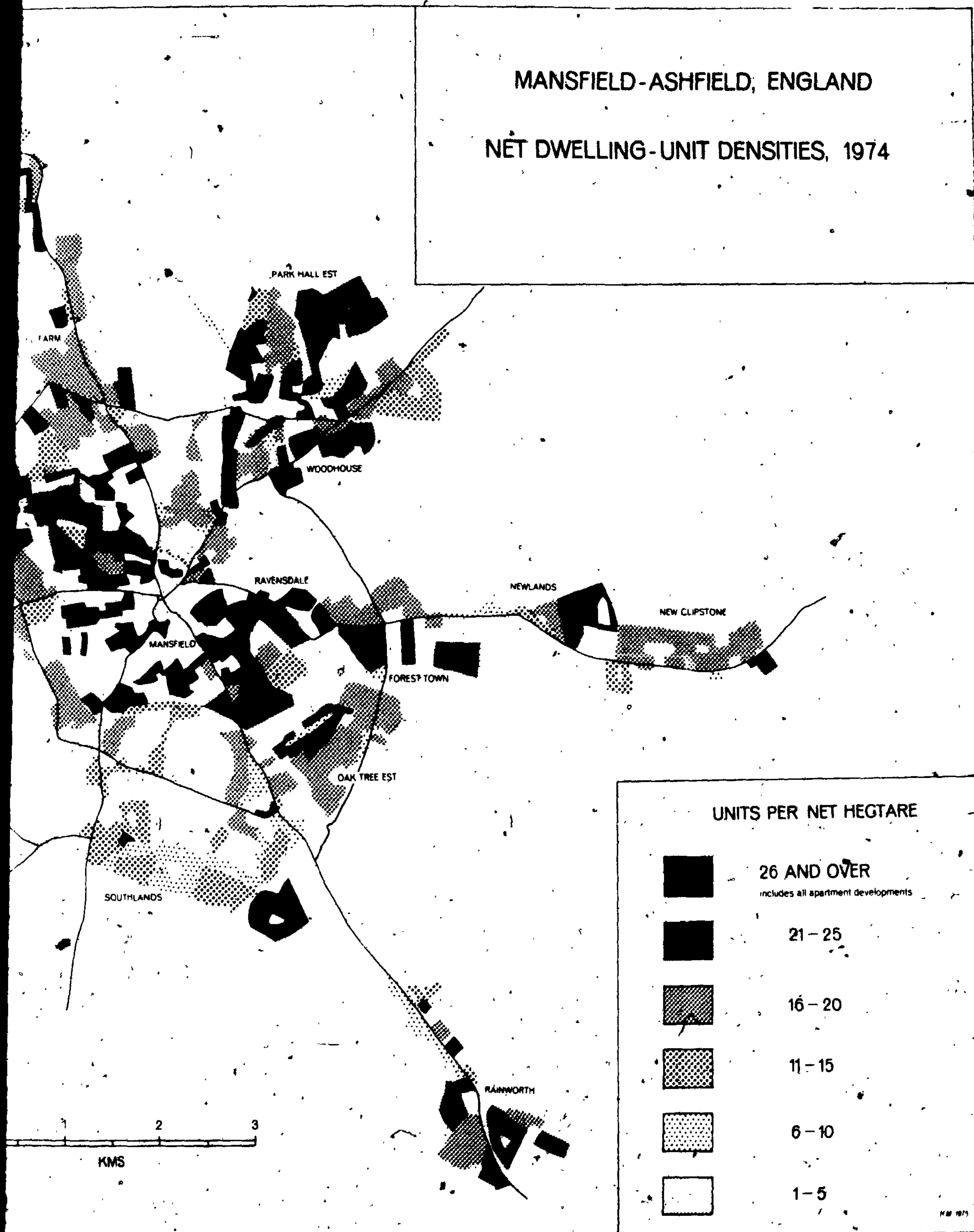
NET DWELLING-UNIT DENSITIES, 1974



0 1 2 3
KMS
STONEYBROOK
Highbury Ave
Huron St
Adelaide St
HURON HEIGHTS
Oxford St
Dundas St
ARGYLE PK
Clarke Sideroad
FAIRMONT
GLEN CAIRN
Commissioner's Rd
Wellington St
Wharncliffe Rd
SOUTHDALE
Southdale Rd
WESTMINSTER PK
NORTON ESTATES
UNITS PER NET HECTARE
26 AND OVER
includes all apartment developments
21 – 25
16 – 20
11 – 15
6 – 10
1 – 5

FIGURE 29

[redacted]


MANSFIELD-ASHFIELD, ENGLAND
NET DWELLING-UNIT DENSITIES, 1974
PARK HALL EST
FARM
WOODHOUSE
RAVENSDALE
NEWLANDS
NEW CLIPSTONE
MANSFIELD
FOREST TOWN
OAK TREE EST
SOUTHLANDS
RAINWORTH
1
2
3
KMS
UNITS PER NET HECTARE
26 AND OVER
includes all apartment developments
21 – 25
16 – 20
11 – 15
6 – 10
1 – 5

(Southlands and Oak Tree Lane). In terms of the variety of density conditions within each city, density levels are distributed in Mansfield-Ashfield such that areas of uniform density are seldom extensive. In London, whole subdivisions (e.g., Oakridge Acres, Orchard Park, Glen Cairn) are developed at almost uniform densities. Within particular regions of the urban area Mansfield-Ashfield therefore displays a greater diversity of densities, a fact related to the scale of urban organization.

The maps of net density distribution are only a summary of data collected for each small area; data give the area location, area in hectares, plus the time-period of development. They are aggregated by density interval and time-period to produce a matrix of actual numbers built in each interval per period (Appendix D). For purposes of trend comparison, however, it is more useful to note the proportions (percents) in each interval developed per period (Table 6), and the proportions in each interval existing in each period (Table 8).

Densities of New Dwellings per Period

In summarizing the figures given in Table 6, medians are better indicators of central tendency than means, since the distributions per period are generally quite skewed (means per period are plotted in Figure 26 only for purposes of comparison with mean road densities). Interquartile ranges are also more appropriate than standard deviations in representing within-city variation in densities per period, and are tabulated along with the medians in Table 7.

In examining these density figures, let us look first at within-city variations. London's range (R) remains low in all period, below

TABLE 6

SINGLE-FAMILY DWELLING UNIT DENSITIES--PERCENTAGE OF NEW UNITS BUILT PER PERIOD IN EACH OF TEN NET DENSITY INTERVALS

Density--Units per Net Hectare	Pre-1880	1880-1920	1920-1950	1950-1962	1962-1974 Detached	1962-1974 Attached	1962-1974 Total
LONDON							
1 - 3	-	0.5	2.3	1.5	0.3	-	0.2
4 - 6	1.9	1.5	8.5	14.4	7.6	-	5.3
7 - 9	2.1	0.4	21.6	44.2	44.4	-	30.6
10 - 12	37.6	13.1	32.3	39.0	35.6	0.4	24.0
13 - 15	38.6	60.1	33.8	-	13.1	9.5	12.0
16 - 18	16.9	20.7	1.4	0.9	-	14.7	4.6
19 - 21	2.9	3.6	-	-	-	14.3	4.5
22 - 24	-	-	-	-	-	11.7	3.6
25 - 27	-	-	-	-	-	7.8	2.4
28 - 30	-	-	-	-	-	25.7	8.0
Over 30	-	-	-	-	-	15.8	4.9
MANSFIELD-ASHFIELD							
1 - 3	-	-	1.2	-			0.3
4 - 6	2.0	0.5	0.5	-			0.5
7 - 9	2.2	0.3	3.0	0.4			2.8
10 - 12	1.2	1.7	4.7	3.7			4.9
13 - 15	3.5	0.9	8.5	6.4			4.9
16 - 18	3.8	11.1	24.5	17.6			12.8
19 - 21	1.5	11.7	27.4	27.6			17.6
22 - 24	-	6.2	19.0	24.6			31.3
25 - 27	1.3	13.5	5.9	12.1			16.5
28 - 30	5.0	6.3	4.4	6.4			1.5
Over 30	79.5	47.8	0.9	1.2			7.0

TABLE 7

QUARTILES OF NET DENSITY--NEW DWELLINGS PER PERIOD

Dwelling units per net hectare	Pre-1880	1880-1920	1920-1950	1950-1962	1962-1974
LONDON					
Lower quartile	11.18	12.97	8.47	7.12	8.42
Median (M)	12.82	14.22	11.13	8.82	11.25
Upper quartile	15.07	15.46	13.41	10.65	17.49
Interquartile range (R)	3.91	2.49	4.94	3.53	9.07
100R/M	30.5%	17.5%	44.4%	40.0%	80.6%
MANSFIELD-ASHFIELD					
Lower quartile	32.52	21.18	16.37	17.96	18.22
Median (M)	46.55	29.44	19.33	20.87	22.10
Upper quartile	74.09	45.12	22.33	23.84	24.50
Interquartile range (R)	41.57	23.94	5.96	5.88	6.28
100R/M	89.3%	81.3%	30.8%	28.2%	28.4%

5.0 units of density except for the marked increase to 9.07 in the final period. Mansfield-Ashfield's range decreases through time from the very extreme figure of forty-two density units down to a fairly constant range of about six units. The increased range in London is owing to the substantial numbers of row-housing units developed during the 1960's and up to the present; these may fairly be thought of as an innovative response to higher land costs caused largely by planning controls.[12] A measure of relative variation, analogous to the

[12]Clawson and Hall (1973) give considerable evidence that in both the U.K. and U.S.A. land-use planning controls have resulted in

coefficient of variation and given as 100R/M, shows that the degree of variation has recently doubled in London, whilst it remains constant at a low level in the English city. One is tempted to view these figures on relative variation of density levels per period as indicative of housing inequalities, if one reasonably assumes that space demanded increases with income. Certainly, it may be stated that single-family land allocation in the Canadian city is considerably more unequal at present than in Mansfield-Ashfield, and remarkably so if one also considers the large multiple-family sector in London.

Although the two cities have differing histories with regard to within-city variation, Tables 6 and 7 show that between-city differences in density levels have decreased rapidly. Not only do the two urban areas seem to have followed parallel trends in median density in response to similar factors, but there has been a marked decrease in the gap separating their typical density levels. This homogenization through time is evident in Figure 30, which replicates graphically the medians and quartiles given in Table 7.

Note that there have in fact been two convergences separated by a divergence. All may be explained with reference to changes

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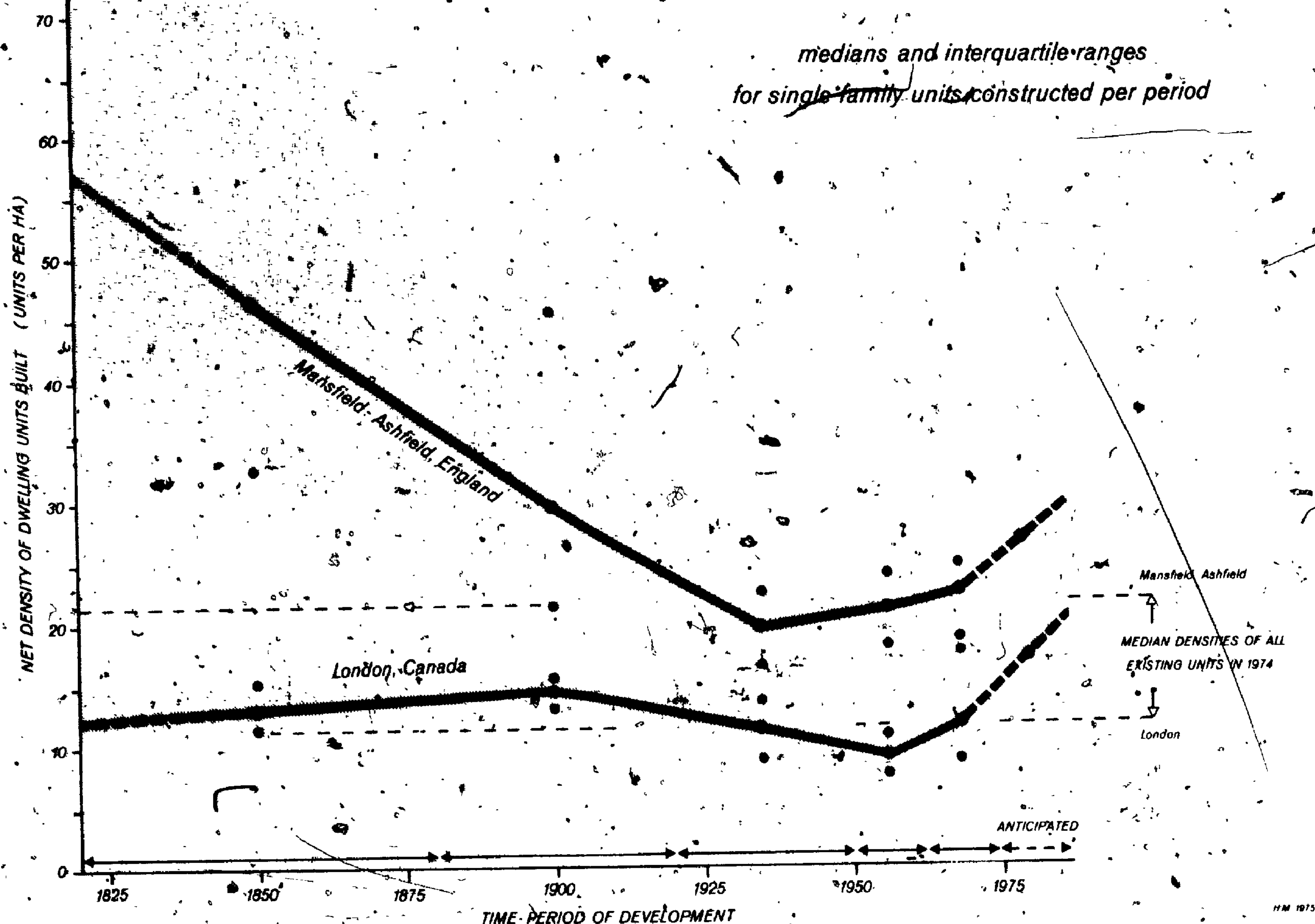
higher site acquisition costs and subsequently greater disparities in net density levels as producers adopt one of two strategies: either switching to the higher end of the market, where rising land costs are less serious in relation to the final selling price, or maintaining lot price as a constant proportion of final price by raising densities. Both types of adjustment have been evidenced in the British private market. The situation in London is similar; the Ontario Economic Council (1973, Ch. 11) points to the municipal planning process as the major cause of greatly increased land costs in the province, whilst oligopolistic land banking may be suggested as a further market distortion affecting the price of serviced lots in London.

FIG 3O

NET DWELLING-UNIT DENSITIES IN EXAMPLE CITIES

medians and interquartile ranges for single family units constructed per period



(innovations) affecting the develpment process. The first convergence brought about relatively similar density levels during the inter-war period (medians of 11.1 and 19.3), and this was in fact the period when both absolute and relative differences were least.[13] At least three factors influenced this convergence, the earliest being the progressive improvement in density standards in Britain beginning with the Public Health Acts in the latter part of the nineteenth century (Box M in Figure 1). Becoming important in the early twentieth century, increases in general prosperity strengthened consumer ability to demand space (Box D).[14] This ability, however, became particularly effective only with improvements in local transport (Box K). Most important in this respect was the introduction of inter- and intra-urban tramlines in the area, fostering ribbon development of both private and municipal housing (for example, between Mansfield and Pleasley, and Mansfield, Sutton and Huthwaite). The automobile had some effect on densities of private development during the inter-war period, but was at this time a contributing rather than a dominant factor.

The last two factors were also operative in the Canadian context. Pre-1880 density levels in London were largely fixed by the

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[13]The two medians are separated by an absolute difference of only 8.2 density units, compared with 15.2 in 1880-1920, 12.1 in 1950-62, and 10.8 in 1962-74. Looking at relative differences, the English level is only seventy-four percent greater than the Canadian in the inter-war period, compared with +267 percent prior to the Great War, +137 percent in 1950-62, and +96 percent in 1962-74. Refer back to Chapter IV, Section 2, for a discussion of relative versus absolute differences.

[14]In part, an increase in space demands may perhaps also be attributed to changing middle-class values regarding density, which might fit into the framework of Figure 1 at A (and possibly also at X).

initial grid layouts of the city, and the higher levels for 1880-1920 more closely represent true market conditions. A density decline occurred during the inter-war period in response to improved public transport and increased automobile ownership, allowing greater urban spread.

Had it been the only innovative force acting on the land market, the automobile would very probably have maintained the parallel downward trend in density into the 1950-62 period, as the English city became affected by mass auto-ownership after the war.[15] Yet, in fact, Figure 30 shows a divergence of net densities during this period; London's densities continue to decline as further adaptation to the automobile takes place, but those in Mansfield-Ashfield stabilize and in fact increase slightly.

This increase may be attributed directly to the introduction of rigorous planning legislation in 1947, and to subsequent national planning policies urged by the central government. Although town and country planning legislation in England dates back to 1909, the 1947 Act was extraordinary in attempting the abolition of the land market through nationalization of development values and rights,[16] thereby

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[15]Ceteris paribus, mass automobile ownership is an important factor in reducing residential densities, in part because it effectively decreases site costs by ameliorating distance constraints, in part because automobiles themselves require much urban space even within residential areas. For discussion on these points, see Lansing and Hendricks (1967), Thomlinson (1969), and Horvath (1974b).

[16]The development value of land is that portion of total value "attributable to the present market reflection of the hope of securing a higher rental or sale price from a future more profitable use"; i.e., the speculative component of land value. The 1947 Act nationalized

transferring control over all development to the Minister of Housing and Local Government. A free-price system was re-established in stages by 1959, but planning permission is still a necessity for all development and allows much latitude for the implementation of policy.[17] The notion of governmental veto over any and all aspects of development may be considered as an innovation affecting density (basically via Boxes J and M in Figure 1). In Ontario, despite inter-war municipal regulatory mechanisms, and the increasingly powerful amendments to the 1946 Planning Act, such a notion was difficult to put into practise until recently, and is probably less uniformly accepted by planning professionals. But, subdivision control in particular has begun to raise densities in London, as evidenced by the increase for 1962-74 in Figure 30.

Despite the current relative and absolute convergence of density levels (see Footnote 13), the median density of new developments in London is unlikely to match that in Mansfield-Ashfield in the foreseeable future. Currently planned sites tend to bear this contention out. Both White Oaks and Whitehills in London have planned net densities

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rights to this "betterment" value, setting aside £300 million to compensate landholders on the basis of assessed development value in that year. Through a system of development charges no profit could be made from the sale of land. However, blanket compensation was never implemented, and in 1959 all benefits to the state were lost when compulsory purchase prices were set at the market price. For a concise account of the legal basis of post-war British planning, see Clawson and Hall (1973, 158-166).

[17] Policy directives from the Ministry regarding land preservation objectives, preferences for compact and tidy physical patterns, and the almost mandatory requirements of main drainage sewerage systems, have all contributed to increased densities since the war.

of exactly twelve per ha. for detached dwellings (lot sizes of 50 by 100 feet), higher than the median for all single-family units in 1962-74. If attached housing continues to be built at levels of about twenty-five per ha., and to account for one-third of the single-family market, this would indicate a median density in the near future of about seventeen per ha., a significant increase. In Mansfield-Ashfield, the Oak Tree Lane estate is planned for 1,200 units on ninety net acres, giving approximately thirty-three units per ha. A fifty-five acre site at Peafield Lane is planned for a maximum net density of thirty-six per ha. During the next decade, the median density of all municipal housing in Mansfield-Ashfield will be around thirty-five per ha., and that for private housing about twenty, giving an expected overall median around twenty-seven per ha. (versus twenty-two for 1962-74). Thus, in absolute terms, little further convergence between density levels in the two cities is to be expected, but continued relative convergence is indicated (Mansfield-Ashfield's median falling from ninety-six percent greater than London's to fifty-nine percent greater). The anticipated trends for 1974-1986 are shown in Figure 30.

Cumulative Densities of Dwelling, per Period

Table 8 lists proportions of dwellings at various densities for the evolving urban composites. The proportions refer to all dwellings existing at five dates, and may be examined for trends in within-city and between-city variations, as was done above for new units per period. For example, cumulative densities in London show a much more gradual increase in interquartile range (R) in the 1962-74 period than do

TABLE 8

SINGLE-FAMILY DWELLING UNIT DENSITIES--PERCENTAGE OF ALL UNITS EXISTING AT FIVE DATES IN EACH OF TEN NET DENSITY INTERVALS

Density--Per Net Hectare	1880	1920	1950	1962	1974
LONDON					
1 - 3	-	0.2	0.9	1.1	0.9
4 - 6	1.9	1.7	3.8	7.1	6.7
7 - 9	2.1	1.4	7.7	19.2	21.9
10 - 12	37.6	27.4	28.9	32.1	30.2
13 - 15	38.7	47.6	43.3	29.7	25.5
16 - 18	16.9	18.5	13.2	9.3	8.2
19 - 21	2.9	3.2	2.2	1.5	2.2
22 - 24	-	-	-	-	0.9
25 - 27	-	-	-	-	0.6
28 - 30	-	-	-	-	1.9
Over 30	-	-	-	-	1.2
MANSFIELD-ASHFIELD					
1 - 3	-	-	0.7	0.5	0.5
4 - 6	2.0	0.9	0.6	0.5	0.5
7 - 9	2.2	0.7	2.0	1.7	1.9
10 - 12	1.2	1.6	3.3	3.4	3.7
13 - 15	3.5	1.5	5.5	5.7	5.5
16 - 18	3.8	9.4	18.0	17.9	17.0
19 - 21	1.5	9.3	19.6	21.2	20.5
22 - 24	-	4.8	12.8	15.3	18.3
25 - 27	1.3	10.7	8.0	8.8	10.3
28 - 30	5.0	6.0	5.1	5.4	4.6
Over 30	79.6	55.2	24.3	19.6	17.2

densities in new dwellings, since the number of units developed in that period is less than a quarter of all existing units. The ranges largely increase through time, being 3.9 density units (1880), 3.4 (1920), 4.0 (1950), 4.9 (1962), and 5.4 (1974). Figures for relative variation (100R/M) are 30.5 percent, 24.9, 30.7, 42.5, and 46.9, respectively. In contrast, the absolute range (R) decreases monotonically in Mansfield-Ashfield, from 41.6 density units (1880), to 27.1 (1920), 12.5 (1950), 9.8 (1962), and 8.8 (1974); the English city's relative variation figures are, in order, 89.3, 81.1, 57.8, 45.8, and 40.8. Thus, figures for the cumulative dwelling stock differ from those for new units per period in that, for the final period 1962-74, Mansfield-Ashfield still displays a greater range of net density levels, in absolute terms, and almost as much relative variation as London.

Turning to between-city differences in density levels, total dwelling stock in Mansfield-Ashfield lags behind the rapid decrease in new housing density levels evident to the inter-war period; in fact, the median density for all housing reaches its lowest level by 1962. Cumulative medians for Mansfield-Ashfield are 46.6 (1880), 33.4 (1920), 21.6 (1950), 21.4 (1962), and 21.6 (1974). There is a similar lag in London's case, with median density of all stock standing at its lowest point in 1974 (figures are 12.8, 13.7, 13.1, 11.6, and 11.5 per ha., respectively). The smallest absolute difference in the overall density levels of the two cities therefore occurred in 1950. Based on suggested growth rates given in Chapter V, Section 4, and on suggested densities of new developments for 1974-86, the medians for all single-family dwelling stock are likely to rise in both cities in the short-range, to about twenty-three per ha. in Mansfield-Ashfield, and thirteen per ha. in London. Hence, convergence or homogenization of density levels in the urban composites may be expected to occur in relative rather than absolute terms.

3. Trends in Coverage Ratios

In examining the possibility of form-convergence in the two example cities, no attention has so far been paid to the proportions of urban area (particularly residential site-area) which are devoted to particular morphological elements. The figures on densities, both of roads and dwellings, give some indication of the extent to which space is covered by streets and houses, as opposed to open space in the form of lots and incidental public spaces. But, these density measures are length-per-area and number-per-area figures respectively, rather than area-per-area. The distinction is recognized in practical planning situations by the use of coverage ratios as descriptive statistics augmenting density information. For example, the lot coverage ratio is the proportion of lot area covered by structures, and the floor area ratio (a three-dimensional measure) equals the ratio of the floor area of structures to lot area.[18] Areas with similar net densities may have quite varying lot coverage ratios, depending upon the size of the house plans in relation to the lots; the post-war ranch style house led to increased ratios in North America despite initially decreasing net densities.

[18] For definitions, see Martin and March (1972, 32), and De Chiara and Koppelman (1969, 327).

The net area of a developed residential site may be exhaustively split into three broad morphological categories: dwelling-structures, private open space, and public access space (all pedestrian and vehicular access). To determine possible trends in the proportions of these categories, three one-hectare quadrats representative of typical single-family density levels and layout features were taken for each period in each city.[19] For each quadrat, the number of ares[20] in each category were computed by means of a grid overlay, and the figures converted to percentages of net area where necessary. The averaged percentages per period are regarded as being indicative only, but are nevertheless illuminating. They are plotted in the form of a ternary diagram (Figure 31).

In studying this figure, one is immediately impressed by the constancy of proportions evident in London's developments. For this city, the proportion of net area in private open space has been very high throughout, with the exception only of the most recent period. Until 1962, private open space varied between sixty-three and seventy-one percent; area covered by dwelling structures was relatively low (between eleven and seventeen percent), and the publicly-accessible space, being restricted to the street layout, also occupied little net space (between eighteen and twenty percent). Proportions in Mansfield-Ashfield, by comparison, altered considerably up to 1962. Although initially quite different from prevailing Canadian levels (with much

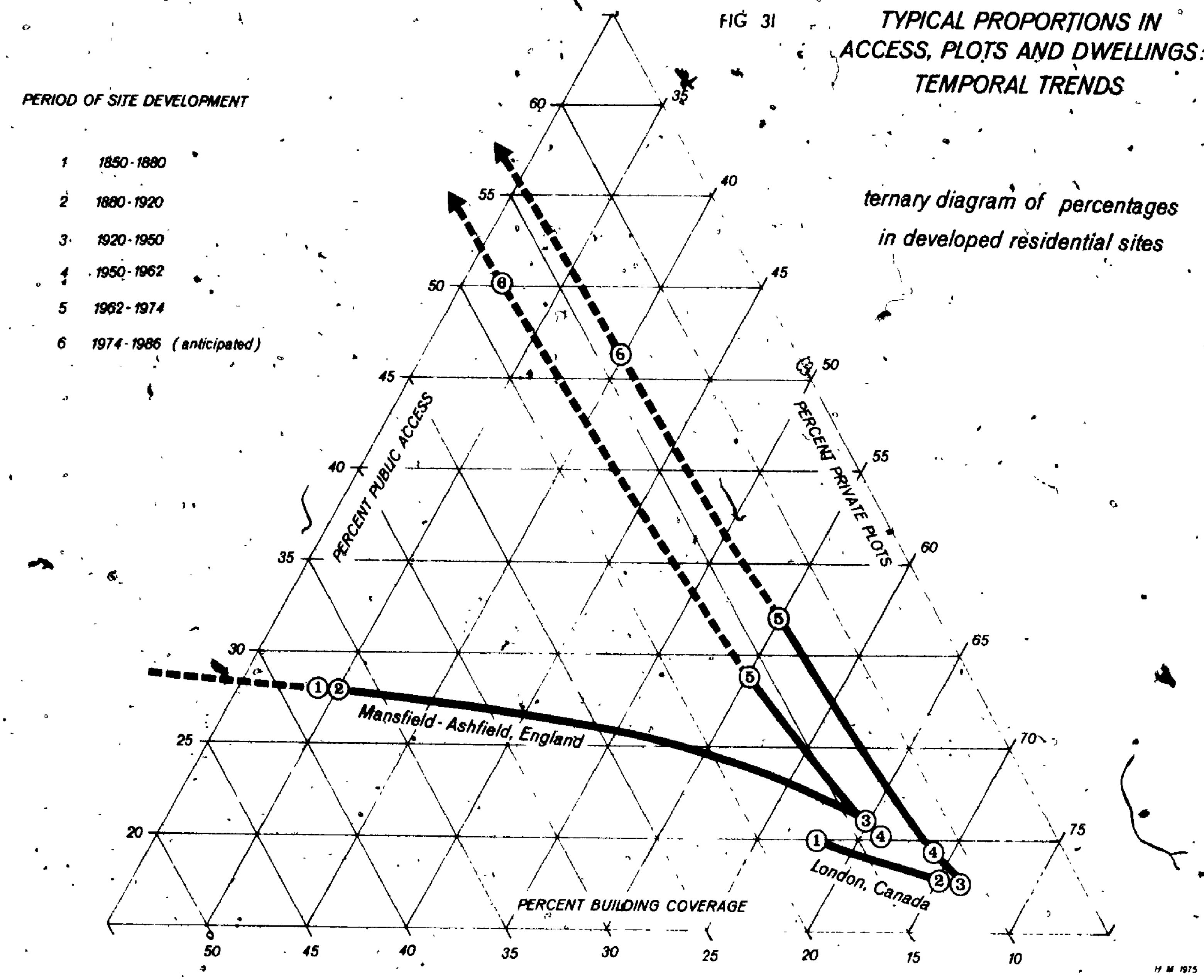
[19] From large-scale site plans (scale of 1:2400 and 1:1250).

[20] One hectare equals 100 ares, an are being 100 centares (square metres).

FIG 31

TYPICAL PROPORTIONS IN ACCESS, PLOTS AND DWELLINGS: TEMPORAL TRENDS

ternary diagram of percentages in developed residential sites



less private space, much more space occupied by dwellings, and slightly more space in public access), by the inter-war period a significant shift brought proportions into close juxtaposition. In the inter-war and early post-war periods, the English developments may be thought of as representing scaled-down versions of their contemporary Canadian counterparts; although net densities were much higher, houses were smaller and therefore lot coverage ratios were almost identical.

After 1962 a further trajectory shift is evident in both cities. The proportions in private lots fall to fifty-five percent of net area, with countervailing increases in public access to about thirty percent. Dwelling structures maintain proportions similar to those in earlier periods, with the figure in the English city remaining slightly higher than in the Canadian city (sixteen versus thirteen percent). These parallel shifts are largely because of the introduction of row-housing in London, and of cluster-housing principles in Mansfield-Ashfield. Both innovations are largely economic responses[21] to the necessity for higher densities brought about by the direct and indirect effects of planning controls.

Figure 31 also plots anticipated proportions in the short-term future. Site plans of planned single-family developments suggest that the trend towards more public space at the expense of private space will continue, probably at an accelerating pace. Building coverage will also continue to rise slightly in residential sites, although in

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[21] See figures on types of unit most suited to various densities in Lynch (1971, 315) and De Chiara and Koppelman (1969, 327). Note that cluster-housing (whether employing detached or row units) also incorporates social and behavioural goals.

the next decade the proportion of net space covered by dwellings is unlikely to exceed twenty percent in either city. The extent to which the present trajectories are extended will depend largely upon the proportional mix of minimum garden to conventional developments; the suggested positions for the next decade are based on an assumed ratio of one to two.

4. Summary

Complementing the detailed description of street-plan forms given in the previous chapter, and utilizing similar methods of analysis through time, this chapter has focussed on trends in dwelling densities and coverage ratios in the two representative cities. The reader may recall that both the design and density of street layouts converged from quite disparate levels until about 1920, after which basically similar trends were evident. In support, data in this chapter show that dwelling-unit densities also have converged toward relatively similar levels, and that no further absolute convergence has occurred since the inter-war period. As densities of new developments continue to rise in both cities, however, there has been, and probably will continue to be, an increase in relative similarity.

The overall convergence of density levels through time may be viewed as an homogenization process, since the suggested causes of fluctuations in new unit densities represent innovations introduced into the market system. Three innovative factors which contributed to the initial convergence (up to the inter-war period) are suggested, these being: (1) improvements in density standards; (2) increases in general prosperity; (3) improvements in local transport. A post-war divergence of densities is also attributable to innovation effects, as London's densities continued to decline in response to the automobile, whilst those in Mansfield-Ashfield were increased by the direct and indirect effects of a vigorous planning philosophy. Convergence resumed in the most recent period as similar planning values and practice were adopted in the Canadian context.

Further evidence of morphological convergence followed by parallel evolution was obtained from an examination of coverage ratios for three morphological categories: dwelling structures, private open space, and public access. Here, innovation effects are particularly evident in a marked trajectory shift for the period 1962-74, caused by row-housing construction and clustering (Radburn) design practice. New developments in the two cities are unlikely to show further convergence in these coverage ratios, but the urban composites as a whole will.

CHAPTER VII.

CONCLUSIONS AND IMPLICATIONS

This research project has assumed that urban plan features are important elements of overall urban morphology, and that owing to their longevity, they may reveal historical trends in the urban development process. It has been suggested that innovations affecting this process might increasingly be adopted concurrently both within and between national sets of cities, so that we may expect cities to become increasingly similar in their plan forms; that is, to display morphological homogenization. For cities in Canada and England (countries fulfilling the assumption of increasingly similar cultural and technological environments), the empirical research has attempted to discern: (a) the current degree of similarity of plan features; and (b) trends in the degree of similarity through time. Some conclusions on the findings will now be presented, followed by a brief discussion of implications for further research, and for the field of urban geography as a whole.

1. On Differences in the Current Urban Composites

The urban plan at any one time represents a cumulative composite of all previous developments, minus features erased through redevelopment (not an important aspect in the medium-sized cities under study).

This is most true of the street-plan, somewhat less true of building plans and property boundaries. Regarding composite street-plans, the comparison of average design measures and densities in ten cities in each country suggested considerable between-nation differences. Although some degree of overlap was observed for most measures, the national distributions showed statistically significant differences for all measures.

Principal component analysis suggested that the two national groups are distinguished most by differences in road density rather than in layout design, but it is worth noting that the difference is by no means large; the average in Canadian urban areas is 12.9 kms. per net km^2, versus 15.7 in the English cities. Current net densities for plan-composites of the two example cities showed a somewhat greater disparity, the overall means being 10.4 versus 20.0 dwelling units per hectare respectively.[1]

Regarding within-group variations, the Canadian cities are less cohesive as a group than are the English cities, particularly with respect to junction frequency, angular deviation and curvature; this reflects the fact that several Canadian cities are very highly gridded and contrast with others in the group. Because all the Canadian cities show evidence of grid structure in their central areas, they display

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[1]By applying the allometric rule with an expected exponent of 0.5, one would expect net road densities to be in the ratio 12.9:17.9. That the English value is much less confirms that English layout designs are not merely scaled-down versions of Canadian designs, but are more efficient in the provision of lot access because they have generally eschewed costly gridiron plans. (Efficiency here refers only to construction and maintenance costs.)

greater within-city variation on the design variables, particularly curvature and angular deviation.

It is worth remembering, on noting these differences, that the urban plan is but one aspect of the city's spatial structure, viewed within a particular range of scale. It may not hold the same importance for the urban dweller as other aspects of form, particularly those at the architectural scale, or those relating to land-use and social organization. But, it is reasonable to suggest that measurements of diversity in the urban plan provide some indication of diversity in other aspects of urban structure. Thus, for example, the modal dwelling-unit density is a fairly sensitive reflection of the general scale of the environment, a matter of much concern to civic designers. And one might suggest that the degree of within-city diversity in such densities is a fairly reasonable indicator of social and economic disparities; indeed, the view that morphology and socio-economic structure are intimately co-related has been advanced by a number of authors.[2] These larger significances of plan form should be borne in mind when examining the evidence on convergence of plan features.

2. On the Increasing Similarity of Plan Features

The major thrust of the empirical work was aimed at identifying temporal trends in the layout design and dwelling densities of new urban development, particularly in residential sites. Most of the work concerned the actual trends in two representative cities, but a

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[2]See particularly, Herbert (1967), Johnston (1968), and Morgan (1971).

generalized picture of trends in all twenty cities was provided by the use of distance from their centres as a surrogate for time of development. In both cases, time was split into discrete periods, with greatest emphasis on the more recent developments.

Both the twenty-city and two-city data suggest that there has been a temporal convergence in both the design and density of street layouts, but the extent of this increasing similarity varies for different aspects or measures. Thus, in the example cities, great similarity in road curvature was evident by the period 1880-1920, and has been maintained since; on the other hand, not until the recent period 1962-74 do the cities show their smallest absolute difference in angular deviation. All street-plan measures were viewed in aggregate by means of the disparity index (P), which suggested that absolute differences in aspects of street-plan were in the main reduced prior to 1900, and that no major reduction has occurred since.

Net dwelling densities also suggested a slackening of form-convergence through time. Absolute differences between medians for the example cities have hardly altered since the inter-war period, but recent trends would appear to move synchronously according to shared influences, and marked relative convergence is expected (that is, the difference will become relatively smaller in comparison with higher absolute density levels). Single-family densities in both cities are increasing quite rapidly, and will continue to do so; median densities in current developments (eleven per ha. increasing to seventeen in the Canadian case, twenty-two rising to twenty-seven in the English case) are above the median densities for all existing single-family stock.

Between-nation form-convergence was also evidenced by the coverage ratios computed for typical developments in the example cities. English developments moved towards their Canadian counterparts, with greatest similarity in the period 1950-62. It was suggested that both areas are presently subject to similar trends in these ratios.

Regarding form-convergence within cities, it appears that this was in fact occurring until the 1960's, but that the introduction of innovative high density housing units and their associated layout styles is likely to increase the diversity of street-plans, dwelling densities and coverage ratios.

3. On Morphological Homogenization

That convergence of form has taken place is not proof of a process of homogenization. For homogenization implies increasingly similar physical characteristics brought about by the operation of shared forces. Thus, the essentially parallel trends in density levels could have occurred coincidentally, through the operation of dissimilar forces, or of similar but independently-derived innovative forces. It seems reasonable, however, to suggest that densities have in fact changed to accommodate such shared innovations as improved transport modes, and similar planning philosophies and practice. This seems equally the case when considering aspects of design, which have changed largely in response to the dissemination of information (ideas and examples) through the professional literature.

One should note that homogenization need not always be reflected in a process of form-convergence; relative differences may remain the same even given continuous simultaneous adoption of innovations, simply because different market systems have relatively fixed constraints (such as land supply, consumer values, and levels of prosperity) which require local adaptations of each innovation.

Decreasing diversity may be regarded in a positive or a negative light depending upon the scale of environment involved, and upon the objective criteria one is concerned to maximize. Thus, an engineer such as Liebrand (1970, 304) views uniformity of layout design as desirable "throughout the town, throughout the country, and indeed throughout the world," presumably because the designs so uniformly employed would incorporate features maximizing safety and privacy, and minimizing cost. More problematic social objectives, such as satisfaction of visual preferences, or maximization of environmental "legibility",[3] might however require a degree of variety, as other writers suggest.[4] But, urban form is three-dimensional, and if one starts to consider perceptions, then one must take into account the minutiae of architectural and natural detail which constitute the townscape. Perhaps it is only at such micro-levels that environmental variety is essential, and urban plan features may quite properly be uniformly structured with respect to economic and human activity criteria.

4. Suggestions for Further Research

This research project represents an explorative attempt to compare trends in the form of the urban physical fabric. Owing to the

[3]See Lynch (1960) and Appleyard, Lynch and Myer (1966).

[4]For example, see Gutheim (1963), Rapoport and Kantor (1967), Dubos (1968), Rapoport (1969), and Stephen Kaplan (1973).

magnitude of the problem, only restricted aspects of form have been dealt with, and comparison also has been restricted to a minimum sample of cities in only two countries. Certain extensions to this research are, therefore, quite apparent:

(i) To extend the sample of cities in each country, particularly to include cities in a range of size classes. This would indicate, for example, whether the design of plan features is unaffected by city size, or whether diffusion effects occur within nations down the urban size hierarchy. As suggested earlier,[5] during any period of development, larger cities will display a greater range of dwelling-types, density levels, and site planning solutions than small cities, simply as a function of the greater number of developments occurring. And they will very probably exhibit innovative forms which are not introduced until later in small cities. Some innovations may be so specific to a particular consumer sub-market that only a large urban area can generate sufficient demand, in which case such designs will not occur at all in smaller cities.

(ii) To extend the method of analysis to other national areas. In this respect, the United States would be a useful third member of a trio,[6] but it would also be instructive to investigate cities in distinctive cultural areas, and less industrially-advanced nations.[7]

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[5]See the discussion on choice of cities, Chapter II, Section 2.

[6]Particularly in view of the excellent comparative work on urban development in the U.S. and Britain by Clawson and Hall (1973).

[7]To the writer's knowledge, the only statistical comparison of large-scale plan features in developed and under-developed countries is by Caminos, Turner, and Steffian (1969).

The present research has been intentionally restricted to countries sharing many commonalities in terms of technology and culture, and we have been able to identify definite convergences in urban form. But, recall the argument[8] that the greater the disparities between urban forms, the greater the opportunity for rapid convergence, as extrinsic constraints became homogeneous. One might, therefore, expect that much greater absolute convergences would be evident if one compares recent developments in quite dissimilar cultures. For example, as the indigenous forms of Asian, Middle Eastern and African settlements are modified by incremental developments adapted to western ideas and technologies, both the incremental and composite forms of such settlements will converge rapidly on those of western cities. However, one would also expect that, since intrinsic constraints would be more disparate in a more diverse set of environments, such cities are unlikely to become as similar to western cities as the western cities are similar to each other.

(iii) To extend the depth rather than breadth of the analysis, by introducing the third dimension of building height. Certain measures such as the floor-area ratio are already available as extensions of the density notion, but it would be considerably more difficult to assess design features in three dimensions without impinging directly on the architect's scale of concern.

(iv) To investigate trends in plan forms with reference to distinctive types of land- and building-utilization. In this report,

[8] The hypothesis concerning the logistic curve of convergence is discussed in Chapter I, Section 2.

attention has been concentrated largely on single-family residential areas, since these form the major urban land-use by net area. But, also important are purpose-built multi-family residential, industrial, and commercial developments, all of which require peculiar plan features.

All these possibilities would extend our knowledge base in a purely descriptive sense, providing further information on which inferences and hypotheses could be based. To identify specific factors operating to shape the form of urban developments, however, would require an investigation of decisions made within a market framework; for instance, what exactly are the utility functions of developers, consumers, and designers? Can particular site planning innovations be traced through a network of professionals and cities to substantiate the diffusion concept?

5. Wider Implications

This concluding section might have been entitled "urban geography and the fixed capital stock of the city," for it is the author's contention that geographers have for some time paid insufficient attention to the "bricks and mortar" of the city. Despite earlier work by, among others, Dickenson (1945), Smailes (1955), Conzen (1960), Ward (1962), and Whitehand and Alauddin (1969), as late as 1970 Badcock felt able to state that "few urban geographers have attempted to analyze the spatial structure of morphological organization of cities." Several geographers have blamed the lack of progress in the field on failures to develop measuring devices, to generate comparative data, and to formulate general theories.[9] But, perhaps even more crucial, has been the failure to develop a relevant standpoint for study other than the traditional view.

This research is viewed as an important contribution to studies of urban built environment in that it goes some way to rectifying these problems. Thus, it develops rigorous and generally applicable measuring techniques, particularly for aspects of the street-plan, which are not merely descriptive of plan form, but also incorporate aspects of their significance relevant to both producers and consumers. Since streets are the major single land-use in urban areas, and constitute heavy capital investments which remain fixed in the environment for long periods, this is in itself very useful. It builds on the notion of plan-generality put forward by Conzen (1960), but avoids the over-detailed and locally-confined categories which he suggested.[10]

The research also answers complaints regarding the lack of comparative studies of plan form and development. What little is available in this area has either been concerned with the subjective appraisal of historical development, disregarding the types of features most prevalent in modern cities, or has comprised architectural examination of pre-selected small areas. Thus, as Harold Carter has

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[9]See, for example, Conzen (1960), Garrison (quoted in Garrison and Norberg, 1963, 463), Badcock (1970), and Carter (1972, 133-157). In a personal communication, Carter has since stated that "measurement devices have since been developed but there is still no successful theoretical framework into which they can be built."

[10]The most similar study in this respect was by Johnston (1968). But, aside from the omission of street-density measures, his study fails to provide sufficient rationale for the significance of the design measures used.

noted, "most studies of morphology tend to concentrate either on small parts of large cities or upon small towns where the plan can be considered as one whole."[11] In attempting a comparison of modern plan forms, the alternative is to employ sampling designs which provide the benefits of both approaches. As far as the writer is aware, only Johnston (1968 and 1969) has employed sampling in this regard, and his studies are concerned only with one major city, rather than with sets of cities. The approach of sampling small areas of street layout within sample sets of cities is considered to be an important contribution of the present research.

The notion of morphological homogenization is considered to be a useful contribution for the study of urban physical stock. It is contended that it provides a standpoint more relevant to the modern city than the traditional historical approach. For, although any understanding of present patterns requires an analysis of temporal process, there is a difference between a concentration on unique features and processes peculiar to discrete periods, and the search for underlying and generally operative "macro-processes" which explain continuous trends. Such a macro-process would be the homogenization of plan forms brought about by the diffusion of technologies and ideas affecting the development process. This is a relevant framework for understanding the nature both of the city's present stock inventory and of its stock flow through time. Particularly, the idea of innovations in environmental design takes on significance when one considers

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[11]Personal communication to the author, November, 1973.

that new urban development will increasingly be constructed at the scale of entire cities or city districts. Such developments tend to embody only the most contemporary set of design and density criteria, and therefore to differ greatly from urban areas which have grown incrementally over longer periods of time. Given the assumption that people value what is familiar, and that stress may result if innovations in the environment occur too rapidly or too comprehensively, the ability to detect rates of environmental change could become an important evaluative tool for the urban designer.

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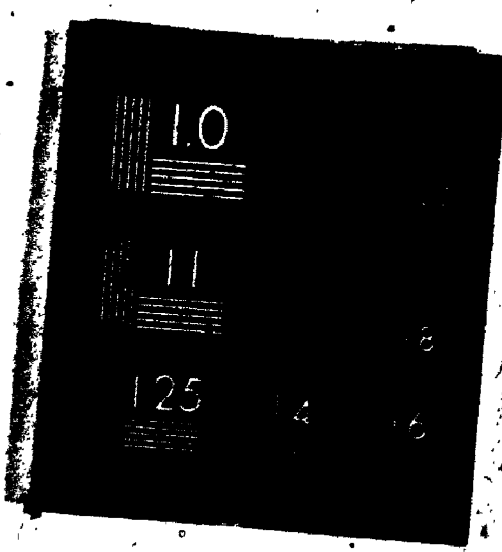

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APPENDIX A

SUMMARY DATA ON OVERALL STREET-PLAN CHARACTERISTICS

	Gross Road Density (kms per km^2)		Net Road Density (kms per km^2)		Road Junction Frequency (junctions per road km)		Road Connectivity (Jctn valency)		Angular Deviation at Junctions (%)		Road Curvature (%)	
	Mean	C.V.	Mean	C.V.	Mean	C.V.	Mean	C.V.	Mean	C.V.	Mean	C.V.
St. John	9.7	48	11.9	37	4.41	69	2.81	18	34	84	34	90
St. John's	10.6	45	12.7	29	4.10	46	3.01	10	47	63	43	56
Sudbury	8.8	40	11.3	36	4.10	13	2.64	13	29	109	34	83
Saskatoon	13.8	17	14.6	15	3.94	27	3.40	12	6	156	10	137
Regina	14.0	19	15.3	13	4.10	24	3.35	14	8	178	10	148
Victoria	10.4	40	13.2	34	4.12	7	2.85	16	30	87	23	93
Halifax	11.7	38	13.6	29	4.41	32	2.90	15	32	83	32	77
Windsor	11.2	35	12.8	23	3.31	30	3.14	20	20	142	5	195
London	10.5	31	11.9	20	3.94	25	3.00	14	11	133	15	111
Kitchener-Waterloo	11.6	26	12.9	17	3.78	44	3.10	11	22	92	24	90
Lancaster-Morecambe	14.6	31	16.9	27	5.98	30	2.75	10	29	54	23	50
St. Helens	11.7	41	15.0	31	6.12	34	2.66	24	23	72	33	36
Cambridge	11.1	32	12.8	23	5.46	24	2.64	10	20	57	15	65
Northampton	13.0	28	14.9	18	4.89	25	2.92	10	28	54	13	83
Burnley-Nelson	18.9	33	21.1	25	7.88	23	2.90	19	20	54	25	52
Oxford	11.8	33	14.1	28	5.52	27	2.71	10	26	68	23	67
Chesterfield	13.0	28	14.8	22	6.46	20	2.67	10	30	49	32	38
Mansfield-Ashfield	12.9	29	15.3	19	5.83	25	2.67	10	32	57	26	60
Blackpool	14.9	31	17.0	22	5.76	21	2.81	12	24	64	19	79
Preston	14.7	47	17.7	32	6.15	22	2.80	22	27	60	23	59
Trois Rivières	13.0	40	14.7	37	4.92	30	3.15	11	21	105	15	118
Average Canadian	11.1		12.9		3.93		3.01		27		24	
Average English	14.0		15.7		5.77		2.71		27		23	

APPENDIX B

STREET-PLAN CHARACTERISTICS--SUMMARY SPATIO-TEMPORAL DATA

City	Zone No.	Sample Size	Road Density Gross	Road Density Net	Junction Frequency	Connectivity	Angular Deviation	Curvature	Distinguishing Features*
St. John	1	7	13.0	13.5	4.4	3.2	15	25	--
	2	7	9.8	11.8	5.4	2.9	24	28	--
	3	11	8.5	10.3	4.0	2.7	37	32	low density irregular curvilinear
	4	5	6.4	11.8	4.1	2.6	62	59	irregular cul-de-sac curvilinear
St. John's	1	4	18.6	18.7	7.2	3.3	34	25	high density irregular grid
	2	9	11.3	12.3	4.1	2.9	49	37	irregular curvilinear
	3	9	7.7	10.3	3.6	2.9	39	48	low density irregular curvilinear
	4	4	6.7	11.4	1.2	3.3	71	60	irregular grid curvilinear
Sudbury	1	8	12.7	13.2	4.7	2.8	23	26	--
	2	10	8.5	11.8	4.3	2.4	27	33	cul-de-sac curvilinear
	3	10	7.5	9.6	3.9	2.3	24	31	low density cul-de-sac curvilinear
	4	6	5.8	9.8	3.3	2.6	38	32	low density irregular cul-de-sac curvilinear
Saskatoon	1	5	15.6	15.7	3.9	3.7	13	6	regular grid rectilinear
	2	15	14.7	15.4	4.3	3.4	8	7	regular grid rectilinear
	3	14	12.7	13.5	3.5	3.3	1	7	regular grid rectilinear
	4	7	11.8	13.4	4.1	3.1	9	23	regular

*See Typology, Chapter II, Section 4.

(cont'd)

APPENDIX B (Cont'd)

City	Zone No.	Sample Size	Gross Road Density	Net Density	Junction Frequency	Connectivity	Angular Deviation	Curvature	Distinguishing Features*
Regina	1	8	15.6	16.0	3.8	3.7	5	2	regular grid rectilinear
	2	13	13.7	15.0	4.4	3.3	11	11	regular grid rectilinear
	3	15	14.1	15.6	3.8	3.5	9	11	regular grid rectilinear
	4	8	11.7	14.0	4.4	2.8	4	11	regular rectilinear
Victoria	1	18	15.2	17.3	4.9	3.2	22	11	high density rectilinear
	2	34	12.8	14.4	4.3	3.0	26	18	--
	3	33	7.3	11.2	3.6	2.3	31	21	irregular cul-de-sac
	4	21	6.9	11.3	3.6	2.6	37	36	irregular cul-de-sac curvilinear
Halifax	1	12	14.4	15.5	5.1	3.2	16	14	rectilinear
	2	25	12.5	13.8	4.5	3.0	37	31	irregular curvilinear
	3	21	10.7	12.5	4.4	2.8	38	35	irregular curvilinear
	4	12	8.9	12.0	3.9	2.7	33	44	irregular curvilinear
Windsor	1	17	14.2	14.8	3.6	3.5	4	4	regular grid rectilinear
	2	25	11.6	13.2	3.4	3.2	14	3	regular rectilinear
	3	24	10.0	11.8	3.3	3.0	20	4	rectilinear
	4	18	8.5	9.9	2.7	2.8	40	12	low density irregular rectilinear
London	1	9	13.3	13.5	4.1	3.3	13	6	regular grid rectilinear
	2	26	10.9	11.9	3.9	3.1	15	11	regular rectilinear
	3	23	9.4	11.5	3.8	2.9	9	19	regular
	4	9	8.8	10.8	3.7	2.8	5	23	low density regular
Kitchener-Waterloo	1	12	14.0	14.3	4.5	3.2	30	18	irregular
	2	15	11.7	12.7	4.1	3.0	24	26	--
	3	14	11.0	12.7	3.2	3.1	22	25	--
	4	9	8.7	11.0	3.3	2.8	7	27	low density

(cont'd)

APPENDIX B (Cont'd)

City	Zone No.	Sample Size	Gross Road Density	Net Density	Junction Frequency	Connectivity	Angular Deviation	Curvature	Distinguishing Features*
Lancaster-Morecambe	1	4	17.7	19.1	7.0	2.7	29	24	high density
	2	10	14.9	17.5	6.4	2.8	32	23	high density irregular
	3	10	18.3	15.5	5.0	2.8	28	23	--
	4	4	18.3	15.5	6.8	2.6	25	26	cul-de-sac
St. Helens	1	6	14.8	16.2	8.1	3.2	22	33	curvilinear
	2	10	11.0	14.2	5.6	2.9	28	30	curvilinear
	3	13	11.7	15.4	5.8	2.6	25	37	cul-de-sac curvilinear
	4	5	8.7	13.1	7.2	2.5	15	27	regular cul-de-sac
Cambridge	1	4	14.7	16.1	6.4	2.8	27	16	--
	2	12	11.3	12.4	5.7	2.6	16	10	cul-de-sac rectilinear
	3	10	10.8	12.0	4.8	2.6	20	18	cul-de-sac
	4	5	7.8	11.7	5.6	2.5	26	17	cul-de-sac
Northampton	1	5	17.0	17.7	5.5	3.1	26	8	high density rectilinear
	2	11	13.2	14.9	4.9	2.9	25	11	rectilinear
	3	4	12.8	14.2	4.4	2.9	23	18	--
	4	8	8.8	12.1	4.6	2.8	37	19	irregular
Burnley-Nelson	1	7	23.4	23.7	8.7	3.1	16	25	high density
	2	10	17.4	20.5	7.6	2.9	23	26	high density
	3	8	19.5	21.6	7.8	2.9	18	25	high density
	4	5	13.9	17.0	6.8	2.8	20	24	high density
Oxford	1	7	13.7	15.8	6.6	2.8	24	34	curvilinear
	2	12	12.1	14.5	5.0	2.8	19	26	--
	3	14	11.7	14.0	5.2	2.7	25	17	--
	4	8	9.3	11.5	5.8	2.5	39	18	irregular cul-de-sac

(Cont'd)

APPENDIX B (Cont'd)

City	Zone No.	Sample Size	Gross Road Density	Net Density	Junction Frequency	Connectivity	Angular Deviation	Curvature	Distinguishing Features*
Chesterfield	1	4	15.2	16.8	6.7	2.9	32	35	irregular curvilinear
	2	7	13.0	15.7	6.4	2.6	24	28	cul-de-sac
	3	6	11.7	12.9	6.3	2.6	30	25	irregular cul-de-sac
	4	4	12.4	13.4	6.8	2.6	39	47	irregular cul-de-sac curvilinear
Mansfield-Ashfield	1	6	17.0	17.6	7.3	2.7	37	31	high density irregular curvilinear
	2	16	12.0	14.3	5.8	2.6	32	23	irregular cul-de-sac
	3	14	12.5	14.9	5.7	2.8	29	30	curvilinear
	4	8	11.8	15.7	5.5	2.7	31	19	irregular
Blackpool	1	8	20.0	20.9	6.4	3.1	31	16	high density irregular
	2	17	16.6	18.2	5.8	2.9	24	18	high density
	3	14	11.6	14.8	5.5	2.7	26	19	--
	4	11	11.8	14.8	5.6	2.6	16	22	cul-de-sac
Preston	1	7	20.6	22.6	7.6	2.9	25	18	high density
	2	11	17.7	20.6	6.4	3.1	25	20	high density
	3	13	10.8	14.5	5.9	2.7	30	25	irregular
	4	7	[illegible]	13.8	4.9	2.5	27	26	cul-de-sac
Canadian Average	1		14.8	[illegible]	4.6	3.3	17	14	grid rectilinear
	2		11.9	13.4	4.3	3.0	23	21	--
	3		10.0	12.0	3.7	2.9	23	23	--
	4		8.5	11.8	3.5	2.8	30	33	irregular curvilinear
English Average	1		17.6	18.8	7.0	2.9	27	24	high density irregular
	2		14.1	16.4	5.9	2.8	25	22	--
	3		12.8	15.1	5.7	2.7	25	24	--
	4		10.9	14.0	5.8	2.6	25	24	cul-de-sac

APPENDIX C

SUMMARY STREET-PLAN DATA FOR EXAMPLE CITIES

Mean Scores per Period	Gross Road Density (kms per km^2)	Net Road Density (kms per km^2)	Junction Frequency (junctions per road km)	Connectivity (mean jctn. valency)	Angular Deviation (%)	Curvature (%)	Distinguishing Features*
LONDON							
Pre -1880 (n=17)	12.09	12.55	3.63	3.25	10.1	4.6	regular rectilinear
1880-1920 (n=12)	11.51	12.65	4.27	3.10	19.5	10.0	rectilinear
1920-1950 (n=17)	9.04	11.51	3.95	2.94	6.8	14.2	regular rectilinear
1950-1962 (n=21)	9.93	11.76	3.79	2.80	11.3	26.1	regular
1962-1974 (n=12)		12.73	5.01	2.53	5.7	36.1	regular cul-de-sac curvilinear
MANSFIELD-ASHFIELD							
Pre -1880 (n= 5)	15.85	16.76	6.88	2.74	43.8	37.0	irregular curvilinear
1880-1920 (n= 6)	14.14	16.26	6.23	2.60	31.3	10.7	irregular cul-de-sac rectilinear
1920-1950 (n=20)	11.94	14.24	5.89	2.60	31.1	21.9	irregular cul-de-sac
1950-1962 (n=13)	12.82	15.92	5.40	2.76	26.9	33.7	curvilinear
1962-1974 (n=10)		16.31	7.89	2.39	15.2	34.5	regular cul-de-sac curvilinear

*See Typology, Chapter II, Section 4.

APPENDIX D

DATA ON DWELLING-UNIT DENSITIES IN EXAMPLE CITIES

Density-Units per Net Hectare	Pre-1880	1880 1920	1920-1950	1950-1962	1962-1974	Total
LONDON						
1 - 3	-	39	185	170	22	416
4 - 6	188	110	669	1,663	605	3,235
7 - 9	213	27	1,700	5,119	3,520	10,579
10 - 12	3,813	955	2,542	4,518	2,757	14,327
13 - 15	3,916	4,371	2,664	-	1,376	12,327
16 - 18	1,709	1,506	114	102	527	3,958
19 - 21	294	260	-	-	513	1,067
22 - 24	-	-	-	-	419	419
25 - 27	-	-	-	-	280	280
28 - 30	-	-	-	-	922	922
Over 30	-	-	-	-	565	565
TOTAL	10,133	7,268	7,874	11,572	11,506	48,353
MANSFIELD-ASHFIELD						
1 - 3	-	3	189	-	22	214
4 - 6	56	49	76	-	42	223
7 - 9	63	24	486	30	231	834
10 - 12	33	159	745	271	409	1,617
13 - 15	99	84	1,365	461	404	2,413
16 - 18	106	1,033	3,928	1,276	1,058	7,401
19 - 21	41	1,090	4,383	1,994	1,451	8,959
22 - 24	-	579	3,036	1,782	2,583	7,980
25 - 27	38	1,255	945	872	1,367	4,477
28 - 30	142	585	708	460	120	2,015
Over 30	2,243	4,447	148	84	576	7,498
TOTAL	2,821	9,308	16,009	7,230	8,263	43,631

APPENDIX E

LOCATION AND HOUSING CHARACTERISTICS OF CITIES SELECTED FOR ANALYSIS

Obviously, the city plan-features analyzed in this work cannot be completely representative of the range of plan-forms encountered in both Canada and England. However, it is felt that the two selected sets of cities display plan-developments which, taken as a whole, are typical of their overall national experiences.

To illustrate this, the following table of housing characteristics is presented. It may be seen that the two sets of cities generally lie either side of the mean figures for all urban areas. Regarding the possibility of regional bias, the location map suggests that this is most in evidence for the English set, particularly with four cities being situated in the county of Lancashire. However, this does not greatly distort the nature of residential layouts in the set of cities, particularly since Blackpool and Lancaster-Morecambe do not share the poor housing conditions typical of Lancashire (indeed, Blackpool appears to be well above the national average in housing quality).

Figures shown in the table are for 1961, for metropolitan areas in Canada, and for central cities in England. The location map plots the location of the selected cities plus all other cities with functional-area populations over 100,000 (see Davis, 1969).

APPENDIX E (Cont'd)

1961 Census Figures	Percent Dwellings Owner-Occupied	Average Number Rooms per Dwelling	Percent Dwellings With 1-3 Rooms	Average Number Persons per Room	Percent Increase in Dwellings*	Economic Indicators: Median House Values ($000's)	Economic Indicators: Proportion Population in Top Four Economic Groups
Saint John	46	5.4	11.7	0.71	21.2	9.9	
St. John's	60	5.7	9.9	0.85	79.8	12.7	
Sudbury	58	4.6	21.7	0.91	93.3	13.3	
Saskatoon	69	5.0	16.9	0.72	99.3	11.8	
Regina	66	4.8	15.8	0.76	97.0	12.2	
Victoria	72	5.0	15.2	0.62	77.4	11.6	
Halifax	55	5.1	16.6	0.79	69.2	14.7	
Windsor	74	5.4	9.2	0.67	55.2	10.3	
London	68	5.3	12.6	0.65	74.2	13.1	
Kitchener-Waterloo	71	5.4	11.3	0.67	78.2	12.4	
CANADA	66	5.3	13.8	0.74	72.7	11.0	
Urban Canada (Cities over 100,000)	56	5.1	15.8	0.72	90.0	14.8	
Lancaster-Morecambe	**	4.7	9.5	0.65	9.0		9.4
St. Helens	34	4.6	8.2	0.73	14.1		6.0
Cambridge	44	5.1	11.2	0.61	18.2		18.8
Northampton	53	4.8	15.0	0.62	14.3		11.4
Burnley-Nelson	58	4.3	10.5	0.66	2.3		9.0
Oxford	49	5.0	11.5	0.66	12.4		14.6
Chesterfield	46	4.6	7.5	0.65	16.9		10.8
Mansfield-Ashfield	42	4.7	9.7	0.65	18.3		9.9
Blackpool	68	4.8	10.3	0.59	16.4		14.3
Preston	51	4.6	8.6	0.66	2.9		7.3
ENGLAND	44	4.8	14.5	0.66	18.2		14.1
Urban England (Cities over 100,000)	***	4.8	11.8	0.67	15.6		11.1

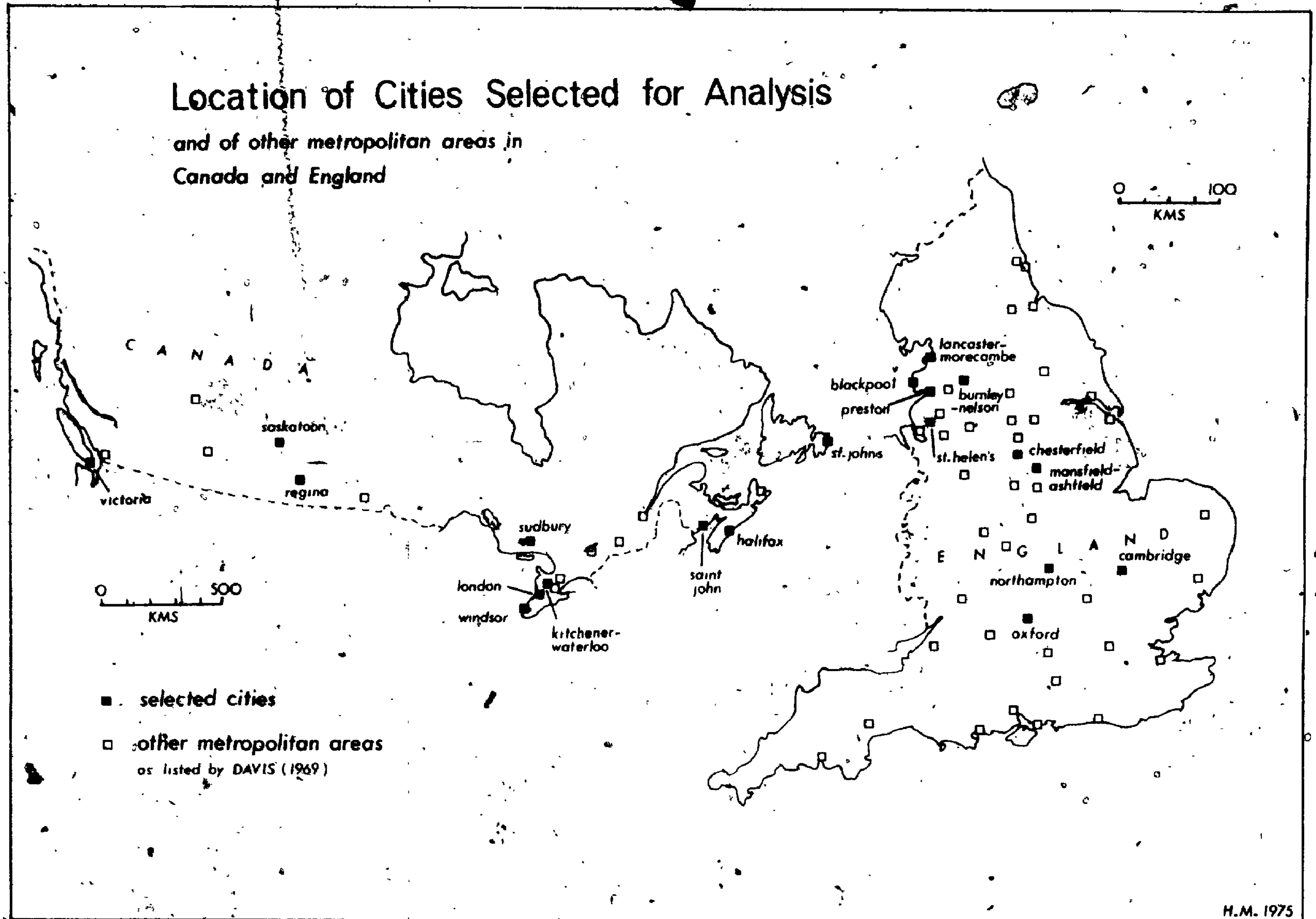
* 1946-1959 in Canada; 1951-1961 in England.

** not available (central city less than 50,000).

*** not available.

Location of Cities Selected for Analysis

and of other metropolitan areas in
Canada and England



APPENDIX F

Loadings for Principal Components Analyses of Street-Plan Variables

		CANADIAN CITIES			ENGLISH CITIES			COMBINED CITIES		
		Comp 1	Comp 2	Comp 3	Comp 1	Comp 2	Comp 3	Comp 1	Comp 2	Comp 3
Net Road Density	Mean	.897	.050	-.081	.215	.932	.076	-.104	.936	.112
	C.V.	-.868	-.244	.006	.408	.169	-.732	.726	-.238	.590
Road Junction Frequency	Mean	-.157	.101	.079	.690	.580	.162	.366	.873	.044
	C.V.	-.081	-.039	.973	.125	-.214	-.757	.112	-.288	.017
Connectivity	Mean	.926	.103	.138	-.468	.835	.141	-.856	-.136	-.025
	C.V.	-.134	-.976	.053	.386	.499	-.621	-.081	.153	.964
Angular Deviation	Mean	-.768	.157	.342	.095	-.145	.171	.860	-.097	-.033
	C.V.	.767	-.272	-.353	-.125	-.196	-.862	-.797	-.484	.174
Curvature	Mean	-.699	.384	.300	.912	.017	-.209	.835	.011	.119
	C.V.	.559	-.575	-.138	-.962	.068	.157	-.803	-.493	.144

NOTE: These loadings are for rotated solutions. Only three unrotated components in each analysis had eigenvalues over 1.0. Proportions of total variance per component were not provided for the rotated components, but may of course be computed from the sums of squared loadings.